MARCH, 1939
No. 389
Vol. XLIII.

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# The Journal of The Royal Aeronautical Society

With which is incorporated The Institution of Aeronautical Engineers

*Edited for the Council by Capt. J. LAURENCE PRITCHARD, Hon. Fellow*

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**THE ROYAL AERONAUTICAL SOCIETY WAS FOUNDED IN 1866**

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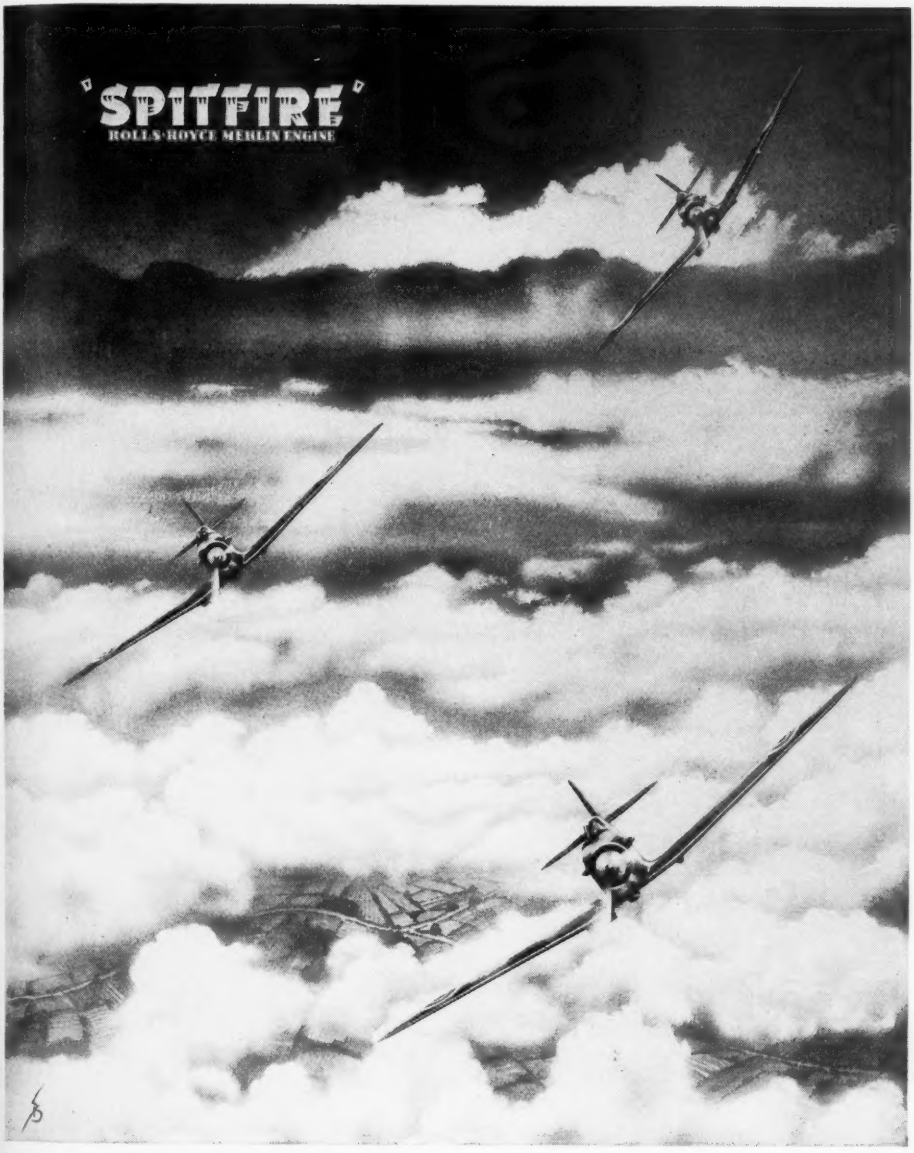


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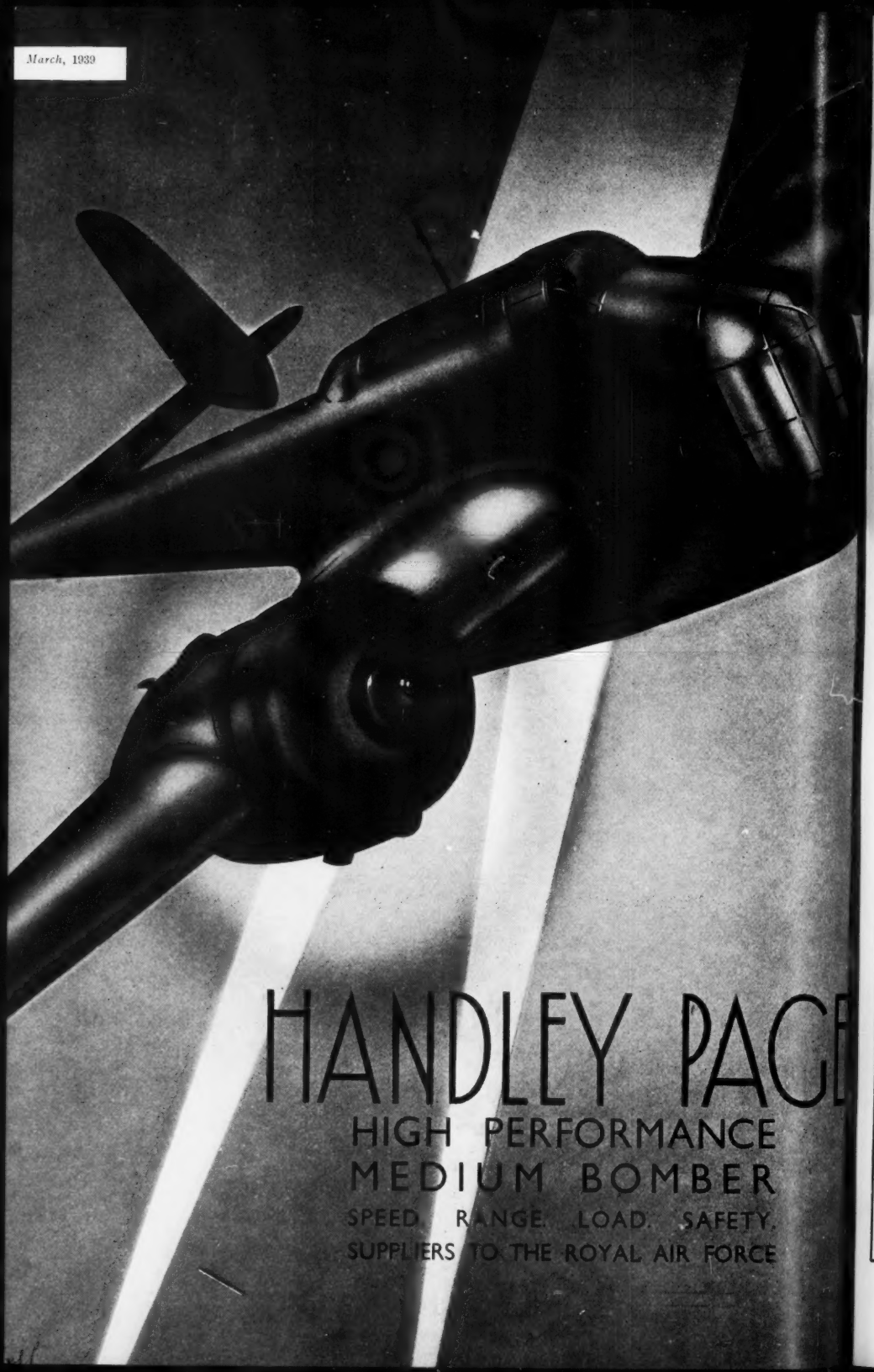
AVIATION WORKS AT WEYBRIDGE, AND
SUPERMARINE WORKS, SOUTHAMPTON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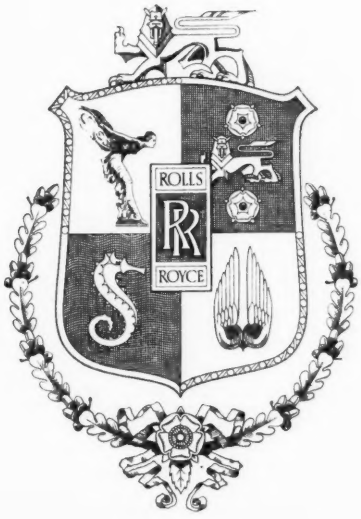
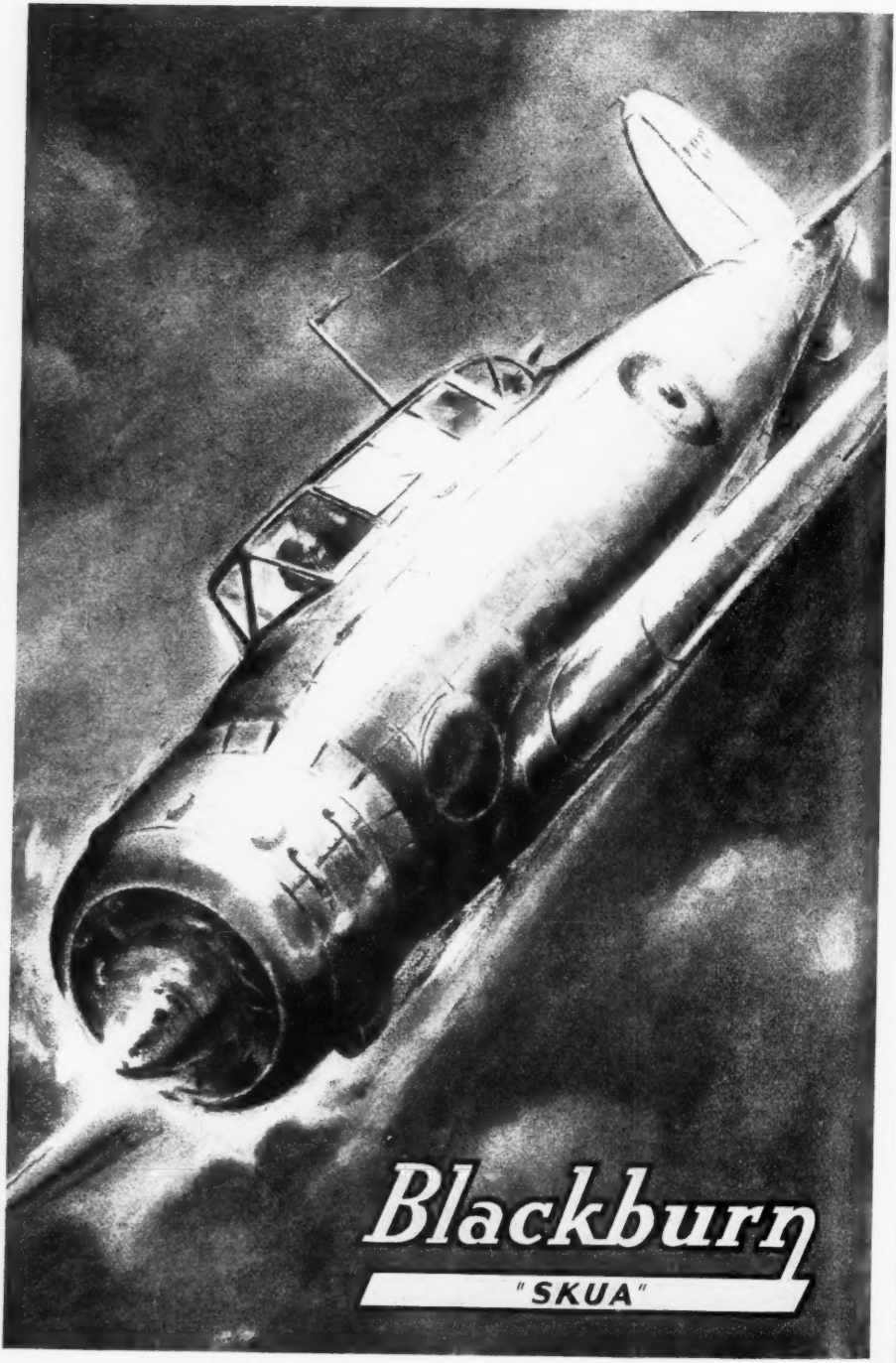
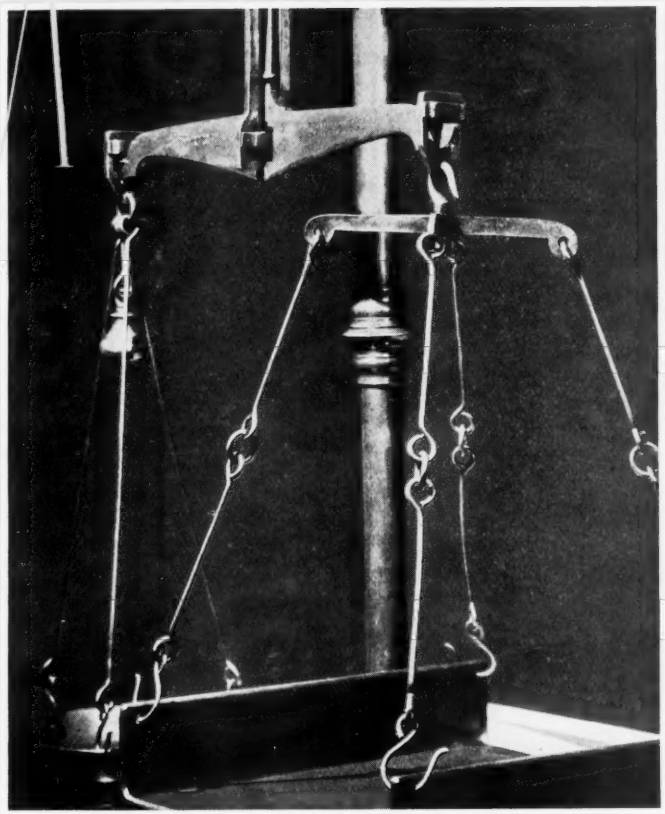



Blackburn
"SKUA"

MARKED BY THE POUND..



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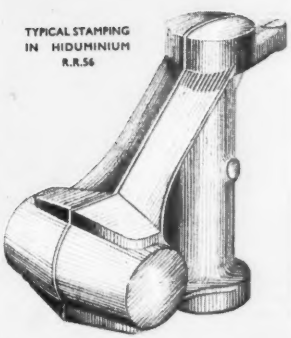

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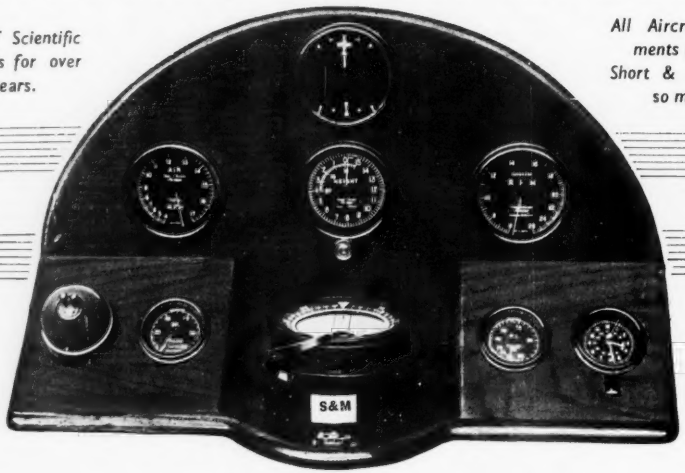


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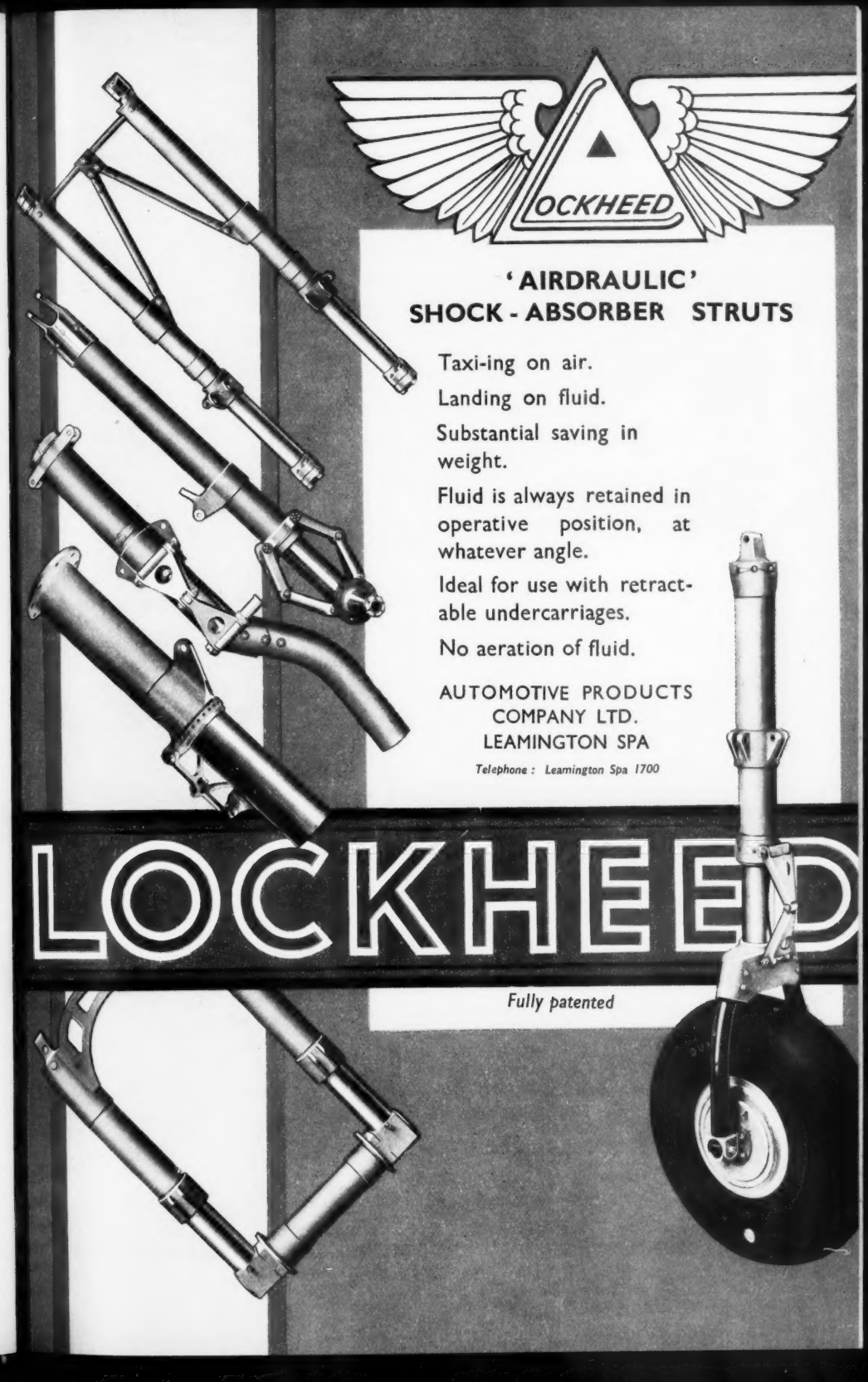
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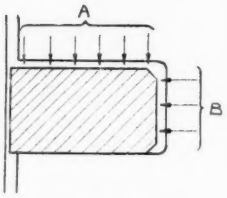


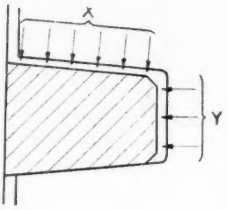


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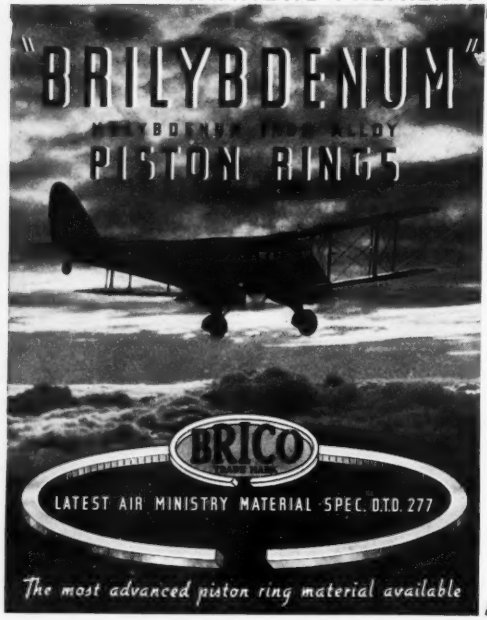


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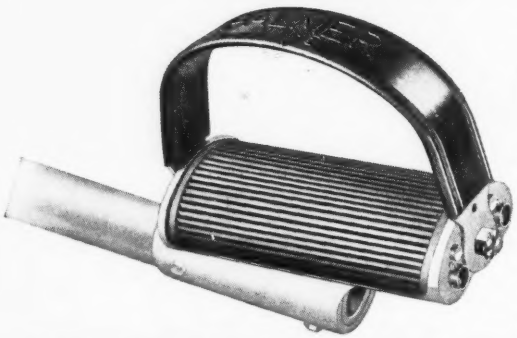

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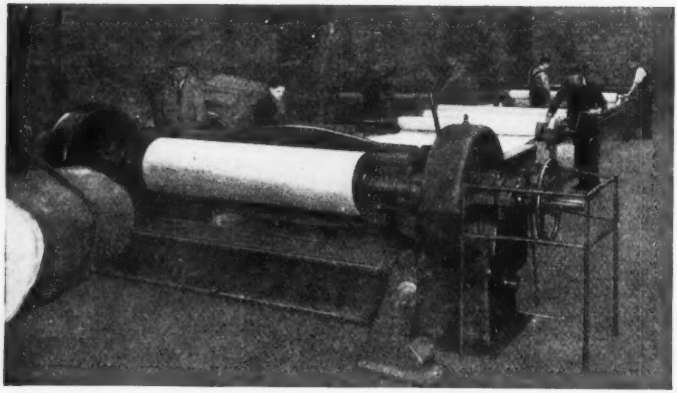

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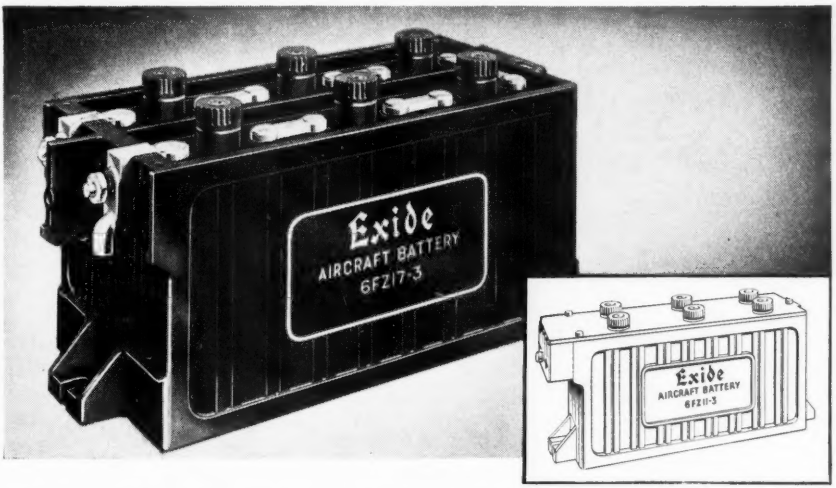


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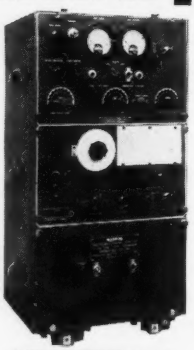

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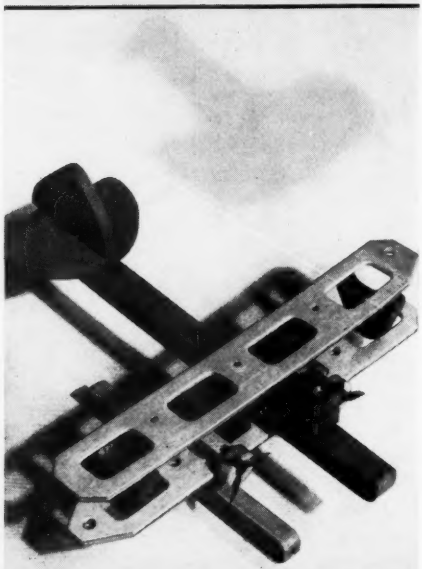

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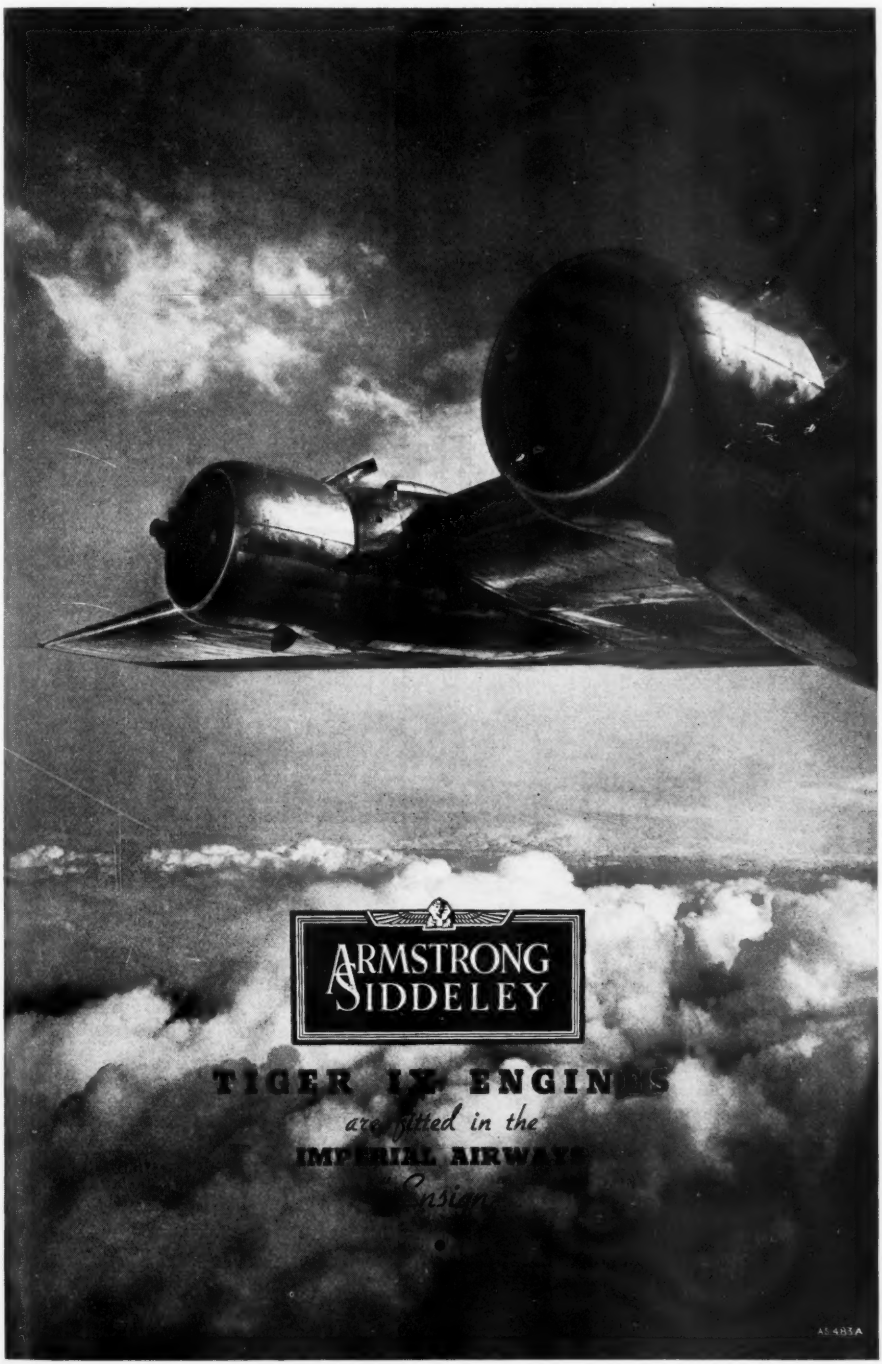
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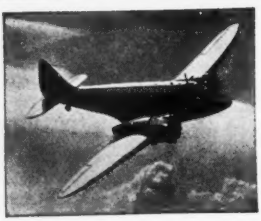

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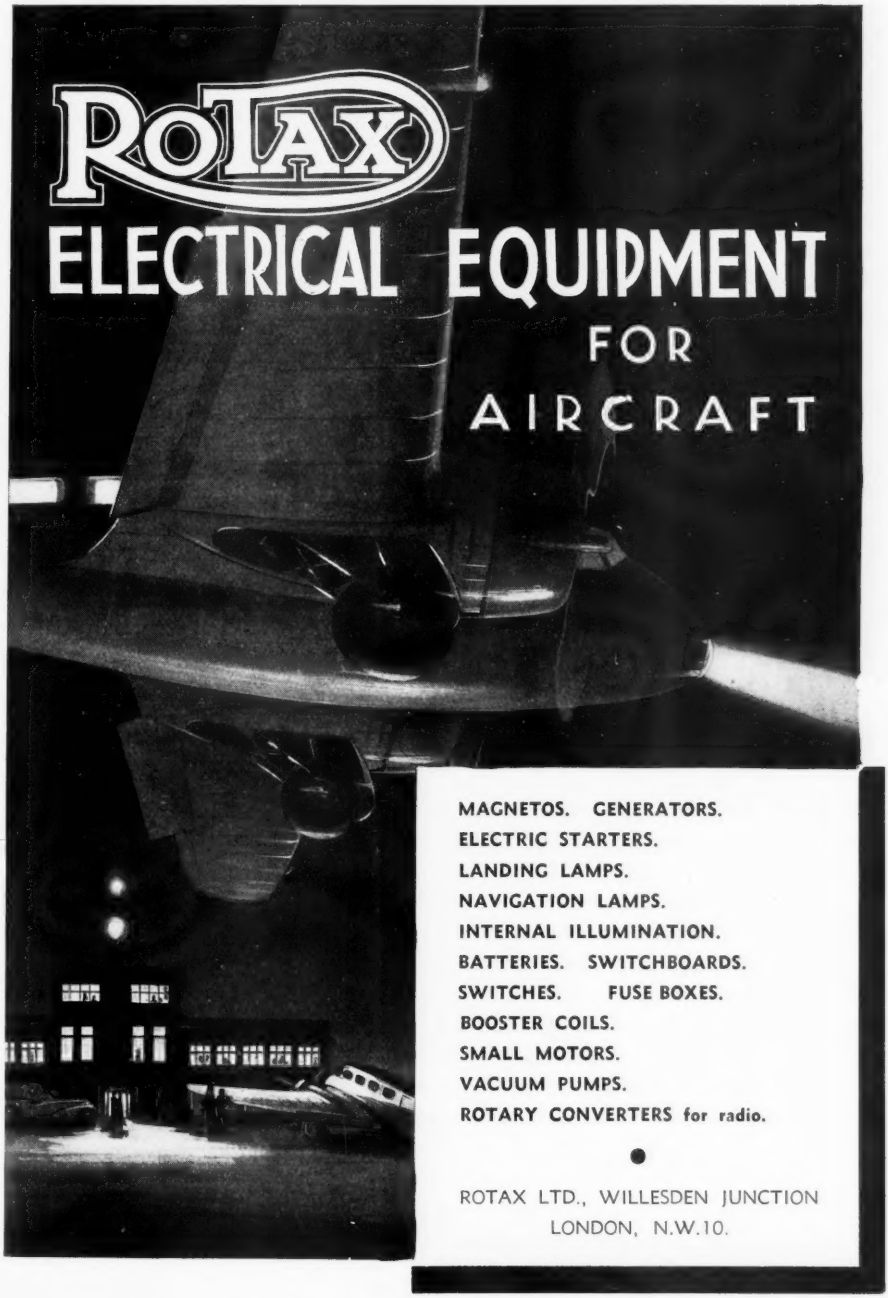
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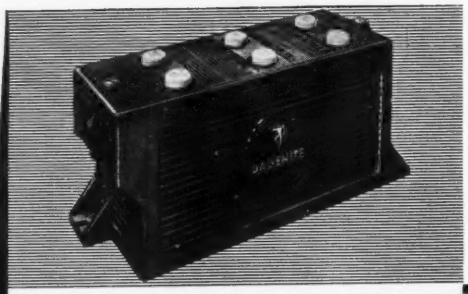

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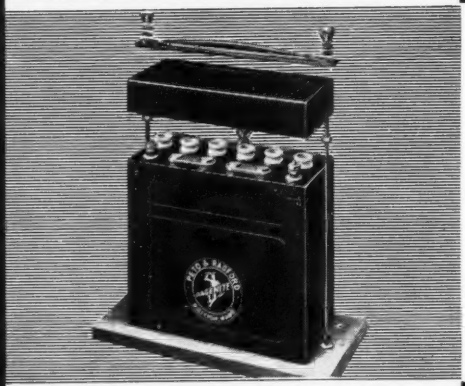

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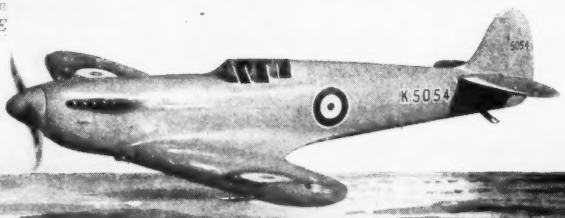


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## PROCEEDINGS.

A meeting of the Royal Aeronautical Society was held in the Lecture Hall of the Institution of Mechanical Engineers at Storey's Gate, Westminster, London, S.W.1, on Wednesday, November 9th, 1938, when a paper on "American Methods of Aircraft Production," by Mr. T. P. Wright, F.I.Ae.S., F.R.Ae.S. (Director of Engineering, Curtiss-Wright Corporation) was presented and discussed.

Mr. A. H. R. Fedden (President) in the chair, expressed his particular pleasure in introducing Mr. Wright, an eminent American aviation engineer, and a personal friend of his own of many years standing. Mr. Wright, he said, was well known by his writings and his work in the United States, and the Society was most fortunate in the fact that, on one of his all too occasional visits to this country, he had consented to lecture to its members.

Although he had become an eminent aviation engineer, Mr. Wright had commenced his professional career as an architect. He had first made contact with aviation during the war, when he had passed the Naval Aviation Ground School Course at the Massachusetts Institute of Technology in Boston, Massachusetts; and later he had joined the Naval Inspection Staff of the Curtiss Company. Ultimately, he had become Vice-President, in charge of engineering, of the Curtiss-Wright Corporation, and he was entrusted with the general engineering policy on aircraft, engines, and propellers, so that his post was one of no mean responsibility.

In 1930 he had been awarded the Medal of the Wright Brothers for aviation. At the moment he was President of the Institute of Aeronautical Sciences (a scientific and engineering society in America which was so closely allied to the Royal Aeronautical Society), and he was a member of a number of aeronautical technical committees in the United States.

It was of the most profound importance, continued the Chairman, that there should be exchanges of ideas between the representatives of two great democratic countries—the United States of America and Great Britain. The policy of exchanging ideas had always been fostered by the Royal Aeronautical Society, and by the presentation of Mr. Wright's paper something more was accomplished in joining the two countries together in friendship.

## AMERICAN METHODS OF AIRCRAFT PRODUCTION.

By T. P. Wright, F.I.Ae.S., F.R.Ae.S.,

*Director of Engineering, Curtiss-Wright Corporation.*

It is indeed an honour to appear before you to address you on the subject "American Methods of Aircraft Production." We in America have long held the Royal Aeronautical Society in high regard, amply justified by the excellence of its published papers and the example it has set in organisation and in the conducting of an aeronautical society. Indeed, a few years ago when several of us in America decided that we too should have an aeronautical society, we planned our own organisation very largely on yours. We are very much pleased that the relationship which has existed between your Society and the Institute of the

Aeronautical Sciences in America throughout the brief career of the latter has been so close and friendly and I can assure you that we intend to do everything possible on our part to continue this highly desirable condition.

In planning my paper it seemed well to divide it into two main sections, one dealing with manufacturing in general, and the other dealing with specific methods used in producing aircraft in America. It will be for you to judge how successful we have been in attaining the manufacturing ideals toward which we are striving. A great many of the methods which we use, perhaps most of them, are similar to those of your country. However, there are several on which I will attempt to lay particular emphasis which are, I believe, peculiar to American practice and, as they are, as well, conducive of economics in construction, will therefore probably be of particular interest to you. So, although the differences will be stressed, in reality, it is possible that the similarities will predominate. In this regard I am reminded of a very quoteable statement of Mr. Hafner: " The paths of progress of independent investigators are all curves asymptotic to the truth and it would be surprising if they did not approach each other."

## Aim of Manufacturing.

Basically, it is perhaps true to state that the aim, or more accurately the philosophy, of manufacturing is to bring into existence useful goods correctly and economically produced for the purpose of raising the general standard of living and creating more leisure for humankind. It is rather sad to contemplate that in producing a preponderance of military aircraft in our industry, we cannot properly claim to have this aim. However, we all must admit the necessity at the present time of manufacturing military aircraft as efficiently as possible in a world such as we find to-day, hoping earnestly for the day when civil aircraft will predominate. More specifically then, our manufacturing aim is to incorporate a designer's idea, as shown on paper, into a structure composed of materials so cut, formed and joined together as to insure retention in the completed structure of the originally assumed installation arrangements, strength values, weight proportions, and aerodynamic characteristics. In addition, mating parts must be strictly interchangeable. All these objects must be efficiently achieved, which means that the aircraft must be produced economically both as to labour and material. To perpetuate the enterprise by furnishing incentive and capital for continuing research and development, a reasonable profit is essential.

The aircraft industry by the very nature of its product has pioneered in the matters of weight economy and aerodynamic efficiency, both of which impose great limitations on the designer, adding to the difficulty of creating a readily buildable product. In this lies our greatest difference from other industries. But a truly successful design is one that not only incorporates these engineering prerequisites, but also can be cheaply and speedily produced; so our problems are manifold.

Because of the predominantly military character of our production, we have, perhaps, sometimes lost sight of the need for economical construction. Yet I feel this to be an error, as economy of construction connotes ability to produce rapidly, which is certainly of tremendous military value as well as being a necessity in the case of civil aircraft. Basically, the requirements of any aircraft, whether civil or military, are the same. Cheapness, in the sense of shoddiness, can never be tolerated in any aircraft, but cost reduction by well thought-out design and by adequately prepared manufacturing tools and methods are of extreme importance.

## Factors Involved in Cost Reduction.

A most important factor in cost reduction is the so-called production curve or variation of cost with quantity. Some time ago I prepared for the Institute of the Aeronautical Sciences a discussion on this subject and presented several curves based on experience available to that time. One of these I will reproduce here as

it indicates the basic nature of this variation (Fig. 1). The curves shown plotted on logarithmic paper are used to determine a cost ratio for varying production quantities. The form of the curve is of the type depicted by the formula: $F$ equals $N^x$. This resolves into an expression for $X$ as: $X$ equals (log $F$/log $N$); where $F$ equals a factor of variation proportional to quantity $N$. The reciprocal then represents a direct variation of cost versus quantity. A curve so plotted appears as a straight line for the factors of labour and material. Each curve is denoted as, an 80 per cent. curve, 88 per cent. curve, or 95 per cent. curve, for labour, purchased material, and raw material, respectively; a ratio having definite significance. This percentage represents the factor by which the average labour or material cost in any quantity shall be multiplied in order to determine average labour or material cost for a quantity twice that number of aeroplanes.

Material costs are lessened by reductions in waste, by more economical buying in large quantities, by better cutting of parts from purchased sheets, and by the reflected effect of labour reduction which some vendor has applied to material prior to receipt in the aircraft factory. This latter cost accounts for the difference in factor for so-called purchased material as against raw material.

When totalling up the cost of these components, by applying the proper proportions of labour, material, and overhead, in order to obtain the cost of the complete aeroplane, the uppermost curve of Fig. 1 is obtained. Although points derived empirically do not exist for quantities of over two or three hundred aeroplanes, it is nevertheless believed that the curve, even as extended above such quantities, indicates with considerable accuracy the relationship of the factors, cost and quantity.

Although reductions in material cost are important and become relatively more so as quantity increases, it is probable that factory methods more directly reflect reductions in cost of labour. The following table gives the approximate relationship between construction labour on the one hand and raw material and also tool cost on the other. These values, particularly those relating to tool costs, are quite approximate and apply to all-metal construction of the type common in America. They must be construed, therefore, as an indication of trend only until such time as a greater volume of cost data is available.

RELATIONSHIP BETWEEN CONSTRUCTION LABOUR COST VERSUS RAW MATERIAL AND TOOL COST.

| Quantity in production | Material to labour | Tool cost to labour |
|---|---|---|
| 1 | 22 per cent. | 8 per cent. |
| 100 | 66 ,, ,, | 25 ,, ,, |
| 250 | 100 ,, ,, | 40 ,, ,, |
| 1,000 | 125 ,, ,, | 50 ,, ,, |

NOTE: Values are quite approximate and apply to all-metal type of construction.

The factors with which we are particularly interested insofar as decreasing the hours of labour is concerned, are the following: Substitution of more efficient machine tools; construction of better jigs and fixtures for production; study of individual operations to eliminate waste motion and effort; and the improvement of the design itself so as to offer for construction a more readily buildable product. In the last part of this paper the methods which we are using in the United States for the actual production of aircraft, and in which are indicated the factors we consider important in attaining the first two aims above, are fully discussed. Some further discussion here appears desirable with reference to the design factor.

The design factor is particularly worthy of attention as, because of the relative youth of the industry, we have not trained sufficient engineers, designers, and draftsmen who are intimately familiar with shop methods. We have had to build up our rapidly expanding drawing offices with men fresh out of college who have

not had the highly desirable apprenticeship of shop experience. Engineering emphasis therefore has, of necessity, been placed on aerodynamic refinement and weight reduction, with production economy as a secondary factor. It is only quite recently, when quantities have expanded sufficiently to definitely warrant it, that careful attention to design from the shop standpoint has come into existence and it is still far from sufficient. No doubt in your country as well as in ours, one frequently encounters antagonism between the engineering department and the shop, due, in large measure, to a lack of sympathy, each for the problems of the other. Better understanding will result when manufacturing considerations are known and appreciated by drawing office personnel and, as well, when shop personnel become convinced of the necessity for the utmost refinement in structural and aerodynamic design.

Some types of design inherently limit reductions in labour beyond a certain point whereas others have, as yet, almost limitless possibilities. As an example, I would cite torch welding as a method of construction which at some point reaches a limit in efficiency. Although this method of construction has been very cheap and much used in America in the past when small quantities of aircraft were produced, it does not appear that in very large quantities it is so well adapted to cost reduction. The hand sewing of fabric is a similar case although there are other methods of fabric attachment which appear to offer possibilities, such as the one which contemplates securing the fabric to the rib through an extruded hole in the latter into which the fabric is led and securely fastened by means of a wire. On the other hand, possibilities of continued reduction of cost in the cutting, forming and fastening of metal are definitely present since these items are susceptible to a continuous programme of labour saving as design and tooling methods progress. Further increases in quantities of planes produced will greatly facilitate this progress.

### Size of the Industry.

The aircraft industry in America is small compared to a great many others. To give us proper perspective when judging our industry, the statistics appearing in the following table are of interest. These indicate that we must, for some time

Statistics on the Size of the American Aeronautical Industry.

1.—*Relative importance in money value of the aviation manufacturing industry compared with certain other industries is in the following ratios:*

| | |
|---|---|
| To the automobile industry ... ... | 1:30 |
| Note.—When considering the higher unit price of aircraft, this figure, in terms of quantity, becomes of the order of 1:1500. | |
| To the tractor, tin can, and refrigerator industries ... ... ... ... | 1:4 |
| To the typewriter industry ... ... | 1:2 |

2.—*In the field of transportation, the ratio of air transport:*

| | |
|---|---|
| To the railroads is ... ... ... | 1:110 |
| To the bus systems ... ... ... | 1:8 |

3.—*Within the aviation industry, the importance of the three major branches is as follows:*

| | |
|---|---|
| Private flying to military aviation ... | 1:5½ |
| Private flying to airlines ... ... | 1:1½ |

4.—*In the carrying of persons or goods by air transport, the relative importance of the various types of cargo, in terms of percentages, is as follows:*

| | |
|---|---|
| Passengers | 62 per cent. |
| Mail | 34 ,, ,, |
| Express | 3 ,, ,, |
| All others | 1 ,, ,, |

5.—*In the manufacturing end of aviation, the relative importance of the component parts of the aeroplane are represented by the following figures:*

| | |
|---|---|
| Planes and spare parts | 5 |
| Engines | 3 |
| Equipment | 1 |
| Total | 9 |

6.—*The rapid growth of air transport in the U.S. is indicated by the following Table:*

| Year | Passenger traffic by air transport | All air transport traffic |
|---|---|---|
| 1929 | ——Practically nil—— | |
| 1932 | $ 5,000,000 | $ 25,000,000 |
| 1937 | $ 23,000,000 | $ 36,000,000 |

to come, expect that it will be impossible to go to the lengths which many other industries do in effecting manufacturing economies. For example, the true production assembly line of the automobile factory is far off insofar as the aircraft industry is concerned. However, on the favourable side of the picture is the fact that we are a growing industry and can therefore hope to improve our methods as expansion progresses.

The size of the average production order in one of our aircraft factories as short a time ago as three years, was about 30 aeroplanes. This average at the present time would, I should judge, be more nearly 100 planes. This latter figure I assume to be substantially less than maintains in your country although even here, relative to other industries, production quantities are small. Therefore, as we must design and tool with definite reference to this relatively small number of a given type which it is likely will be produced, we are restrained from going to the lengths we would like in asking for special machine tools for specific jobs. We must still, in the main, adapt general tools to specific uses.

MATERIALS.

A few words on materials is desirable at this point.

*Wood.*—From the engineering standpoint, wood is a material giving nearly equal values of the strength/weight ratio when compared to those attained by steels and aluminium alloys; and with proper finish, deterioration in service has not been too severe a problem. Yet I believe, from the standpoint of manufacturing in large quantities, metals offer greater possibilities and that we are unlikely to see a reversion to the use of wood in aircraft. How different is the aircraft factory to-day from that which I recall in 1918!

Whereas the woodworking departments now take up perhaps three per cent. of the floor space, they then occupied, I should judge, about 75 per cent.

*Alloy Steels.*—These, particularly chrome molybdenum, play an important part in aircraft construction in America and will, I believe, continue to do so. Chrome molybdenum steel is used in tubing and forged form for engine mounts, landing gears, and highly stressed fittings. Nickel steel is, for the most part, used for bolts and similar parts.

*Non-Ferrous Metals.*—In general, non-ferrous metals other than alloys of aluminium play a relatively unimportant part in aircraft production although quite

a few copper and nickel alloys are found in many of our planes. Brass and bronze are used to a limited extent. Some bronze castings are found and brass in the form of machined bar stock for hydraulic fittings and the like occurs quite frequently.

*Aluminium Alloys.*—This material is, by far, the most important one in American aircraft construction. It has a good ratio of strength/weight, is workable and sufficiently inexpensive to make it attractive. It is particularly well-suited to use in the stressed skin type of construction so prevalent with us at present. It is used extensively both in the forms known as duralumin and alclad; in the latter in aircraft for our Air Corps and for our civil users; while in the former, anodically treated, it is preferred rather illogically for naval aircraft. With increasing structural design efficiency, the problem of securing adequate rigidity is becoming of great importance. Duralumin is only fair in this regard. Although this material is eminently suitable for stressed skin construction, yet from the standpoint of reduced complication we could perhaps wish for one of even lower specific weight in order that for given weight/strength requirements, greater skin thickness could maintain, thus further reducing the need for stringers and stiffeners

*Magnesium.*—Some feel that this material has possibilities in alloy form to supplement or supersede aluminium alloy. However, certain characteristics of magnesium alloys have not proved particularly desirable and so far the chief uses of magnesium are in the form of castings where the material is used extensively for landing chassis wheels, levers, tail wheel forks, and rudder pedals, with some additional use in sheet form for housings, etc. It seems quite likely to me that, eventually, alloys of magnesium will be developed which can properly be used more extensively for structural purposes.

*Plastics.*—We have not, in America, gone far in the development of plastics for uses in aircraft other than small unstressed parts. I believe you, in England, have gone further than have we, judging from the quite numerous articles which have appeared in your aeronautical press. I feel that the material has definite possibilities as a major structural material when suitably reinforced to supplement the physical qualities which plastics lack. We have used thermo setting plastics for ignition system parts, control pulleys, instrument cases, control knobs, electrical switches, insulators, ignition boxes and in radio parts. In sheet form, panel work and decorative fixtures are also made of this material. We have made use of the thermo plastic material in windshields, windows, inspection panels, landing light covers, table utensils, lighting fixtures, and in solution form in dope, wire coatings, etc.

*Stainless Steel.*—The so-called 18-8 (chromium and nickel) alloy is finding favour with more and more designers. The material is used extensively for ammunition boxes and chutes, trays and other accessories. One or two firms in America are constructing complete aeroplanes from stainless steel with creditable results. Technical analyses have shown that structures made completely of stainless steel when compared to those made of the best aluminium alloy are of approximately the same weight. This material is superior to aluminium alloy in ratio of yield point to weight and stress-weight-deflection ratio. It is inferior from the standpoint of tensile strength weight ratio and yield ratio for equal deflection. A figure of merit giving suitable consideration to each of these factors has been made by one of my associates, Mr. L. C. Milburn, with the result that a factor of .979 comparing stainless steel to aluminium alloy is obtained. However, there are several other properties of stainless steel, such as corrosion resistance and ease of spot welding, which are not susceptible of incorporation in a merit factor and in which it excels, so that it appears that those designers who are using stainless steel are justified from an engineering standpoint. I think that the use of stainless steel will increase in relative importance rather than decrease, particularly as larger flying boats are produced. The material does not appear to me so suitable for monocoque stressed skin construction as aluminium alloy and in fact its properties in some respect are the reverse of those desired,

wherein materials of lighter specific weight, such as magnesium and plastics, are indicated. It would work out advantageously, however, in the so-called beam type of construction where fabric covering is used. I can conceive of a very excellent wing design using a stainless steel monospar construction metal covered back to 30 per cent. of the chord and with a light rib-fabric cover construction aft thereof. Certainly this material offers definite possibilities from the standpoint of lower material cost, suitability for fabricating by electric spot welding, and resistance to corrosion.

*General.*—The above is a very rough outline discussing materials at present being used and indicating trends to show that others are being considered. Once a factory is established on the basis of the general use of a given material, such as aluminium alloy in America at present, it is a quite serious proposition to change to another. Before doing so, the several criteria for judging the suitability of a material, discussed by Mr. Glenn Martin in his "Wilbur Wright Lecture" of 1931, must be considered. He gives the following as factors: Strength/weight ratio; shape; endurance; machinability; formability; fastenability; reaction to moisture; atmospheric and temperature changes; defects in uniformity; cost; source of supply; delivery; ease of inspection. It is well-nigh impossible to establish a figure of merit which suitably reflects all these factors. Great deficiency in any of them, however, for a given material, will very likely throw that material out of consideration.

*Special Forms.*—Under this heading may be mentioned castings, extrusions and forgings. A great many castings find their way into each of our aeroplanes although they are not used extensively in the structure. Some manufacturers favour pressings, particularly because of the smaller draught angles possible. Extrusions find very general favour in America because of a quality which can best be described as neatness. In almost every monocoque structure will be found a substantial number of aluminium alloy extrusions in the form of bulb angles, "z" sections, and a great variety of special shapes for which the Aluminium Company of America possesses dies.

Forgings are very extensively used in America, perhaps more so than in England. They are extremely desirable from the standpoint of economy where analysis shows that the quantity of a given forging is sufficient to amortise the die cost involved. It is rather surprising that this quantity can be quite small. In an order of 25 two-seater planes, it will be found economical to use a substantial number of forgings, perhaps 30 to 50, and in an order of 100 planes, 100 to 200 different forgings can be economically utilised. Figs. 2 and 3 show the aluminium alloy and steel forgings used in the Curtiss SBC-3 Navy Scout-Observation Plane and indicate the variety of forms for which this type of part is satisfactory.

## Works Organisation.

There are four major divisions of an aircraft plant in America, namely, the office, sub-divided into executive, sales, and accounting branches; the engineering department; the inspection department and the factory organisation. The following gives the percentage of personnel which is included in these departments and the number of persons employed in a plant having a total of 3,000, which is of the order of size of many of our present works.

It will be noted that under the factory organisation there are two divisions, including so-called overhead departments and direct labour, the latter representing about three-quarters of the total works personnel. It would be interesting to determine whether or not the relative proportions given above hold for works in your country as well. For an organisation such as the above, the total overhead, or burden expense, to be applied to direct labour when determining cost would range from 60 to 75 per cent.

From the standpoint of factory methods, two items requiring discussion are engineering and planning. A few words concerning the organisation of these departments in American aircraft plants will therefore be given.

ASSUMING AN AEROPLANE PLANT WHICH EMPLOYS A TOTAL OF 3,000 PERSONS, THE MAIN SUB-DIVISIONS OF SUCH PLANT WOULD THEN EMPLOY THE FOLLOWING PERCENTAGES AND NUMBER OF MEN.

| Sub-Division | Percentage | Number of men |
|---|---|---|
| Office (including executive, sales, and accounting) ... ... | 2 | 60 |
| Engineering department ... ... | 7 | 210 |
| Inspection ... ... ... ... | 3 | 90 |
| Factory overhead (including superintendents, foremen, time study, purchasing, maintenance stores, shipping) ... ... ... | 13 | 390 |
| Factory direct labour ... ... | 75 | 2,250 |
| Totals | 100 | 3,000 |

*Engineering.*—Our engineering departments include personnel in various subdivisions, much as shown below which indicates percentages and the number of persons who would be involved in an engineering organisation totalling 200. The functions of each, I believe, are apparent from the designations given.

IN AN AEROPLANE ENGINEERING ORGANISATION ASSUMING THAT THE TOTAL NUMBER OF MEN ENGAGED ON A PROJECT IS 200, THE NUMBER COMING WITHIN THE SEVERAL BRANCHES OF AERONAUTICAL ENGINEERING WOULD BE AS FOLLOWS:

| | | |
|---|---|---|
| Project engineers ... ... ... ... ... | | 6 |
| Aerodynamic section ... ... ... ... | | 6 |
| Weights section ... ... ... ... ... | | 8 |
| Structures section ... ... ... ... ... | | 16 |
| Designers ... ... .. ... ... ... | | 4 |
| Draughtsmen:— | | |
| Layout and leadmen ... ... ... | 16 | |
| Detailers ... ... ... ... ... | 100 | |
| Tracers ... ... ... ... ... | 24 | 140 |
| Others, including blueprinters, clerks, etc. ... | | 20 |
| Total | | 200 |

A word, perhaps, may be of interest concerning our so-called project engineers who are engineering managers and, quite frequently, designers as well of a given project. It is their duty to co-ordinate the efforts of the draughtsmen, weight engineers, structural analysts, designers and aerodynamicists. It is also their duty to effect proper co-ordination with the factory organisation in connection with specifying a design which can be fabricated by tools and methods with which the factory is familiar or are available for procurement and familiarisation. This need for co-ordination at the outset cannot be too strongly emphasised and the success or failure of a job, particularly financially, usually is measured by the managerial and executive ability of the project engineer. Because of the rapid technological advances of the industry, augmented frequently by the inexperience of draughtsmen in production methods, the change order has become a serious problem with all aircraft engineering and factory organisations. Frequently, change orders issued after initial drawing releases have reached quite appalling numbers and many conferences have taken place in an attempt to remedy this situation. I have often

felt that a trite saying which I heard some years ago, should be firmly implanted in every aircraft engineer's mind: "When it is not necessary to change, it is necessary not to change." One important distinction which it is frequently difficult, sufficiently, to instil into the consciousness of our engineers and others has to do with maintaining proper sequence in research, experimental development, and production. Obsolescence has, I believe, overtaken many designs prior to their entering the production stage because of the failure of someone along the line to make this distinction. Something that is purely research should not be incorporated in an experimental design without some initial tryout, nor should research and experimental development find their way into production until thoroughly tried out. "Many an ideal gain must wait until a way can be found to incorporate it without disturbing the existing balance of forces and materials."

A moot question frequently before our engineering departments and works organisations for consideration is the extent to which production methods should be incorporated in prototype designs. Initial incorporation of what may be termed production construction frequently adds to weight and causes delay in getting out the prototype, thus jeopardising the success of the job, either from the engineering standpoint or from the standpoint of delayed completion. On the other hand, if the prototype should prove successful and worthy of placing in production, there is then a long lapse of time frequently present incident to re-vamping the drawings to convert them into production drawings from experimental drawings. The tendency at present, however, is, I believe, towards making experimental drawings more nearly susceptible of immediate production application, on the assumption that with modern engineering methods available, the prototype has a better chance of success than heretofore. The engineering departments of most American aircraft companies have a production engineering section whose duty it is both to advise engineers and designers on experimental projects as to production problems of a given design and to re-check experimental drawings for production changes when quantity orders are received. One example in this regard is the extent to which the incorporation of forgings in experimental designs is warranted. It is difficult to fabricate simulated forgings experimentally from solid stock; therefore, the use of built-up parts is the alternative. However, it is difficult to make the change from built-up parts to forgings unless clearance consideration of the latter was initially given. So here there is a definite trend toward initially calling for forgings on the experimental job, fabricating the part experimentally by the so-called pantograph die-sinking miller by means of a wooden pattern, from rough forgings or bar stock, or by substituting a built-up part.

Some of our aeroplane factory engineering organisations are now acquiring the services of engineers previously employed in the automobile field in order to bring their experience of true production methods to our aircraft engineers. When our company first followed this practice, we were all surprised at the tremendous number of automotive production methods applicable to aircraft work and helpful in reducing production costs, but of which we had not previously been aware; this, in spite of the fact that our production quantities do not permit serious consideration of assembly-line methods.

Important though this necessity for incorporation of suitable production methods on drawings is, our engineers must never lose sight of the fact that their chief emphasis must be placed on aerodynamic and structural refinement, relying to a considerable extent on the ingenuity of the shop organisation to develop a good means of producing the resultant parts. They must constantly bear the need for this emphasis in mind or else unsuccessful prototypes with no subsequent production are likely to result. In this regard, sight is frequently lost of the tremendous value to the civil user of aircraft and, of course, to the military user as well, of weight saving and speed. Analyses recently made, based on operating costs of large transport planes, indicated that an increase in cruising speed of one mile per hour is worthwhile of attainment to the operator if it costs 2,500 dollars to achieve. Similar analyses to determine the value of weight saving yield a figure of 75 dollars

per pound. Such values vary, depending upon the specifications of the particular aeroplane involved and the route over which it is to be operated. There are also economic factors applying to each particular case which affect final judgment. Perhaps as a general statement it would be fair to place the value of weight saving at 30 dollars per pound and of cruising speed increase at 1,000 dollars per mile per hour. Such figures do serve, however, as a useful guide to the engineer in determining the extent to which he should go to attain aerodynamical and structural refinement. The old conflict of standardisation, following known production methods with attendant fettering of ingenuity on the one hand, and so-called prima donna engineering resulting in unbuildable products on the other, becomes involved. A fine balance of judgment on the part of the chief engineer is required.

In my own organisation we have recently developed an interesting method of making possible the rapid preparation of a bill of material or parts list of an assembly or of the whole aeroplane. By this method, every drawing is coded on a card as to material specification and part number. The machine into which these cards are then sorted is the Hollerith accounting machine used by the accounting department for their record keeping. The information on the card is indexed by a series of holes punched at definite locations on the card and by virtue of which the Hollerith machine accomplishes the sorting operation. A complete bill of material can, by this method, be prepared in two or three days, an operation which formerly took four to six weeks (Figs. 4 and 5).

The final objective of an engineering department is to issue releases of drawings to the planning department. The release sheet which accomplishes this result contains part number, part name, material specification, and quantity, together with information on the number of parts required per aeroplane. It is from this data that the planning department is enabled to function.

Before proceeding to the planning department in this discussion, I should like to mention two or three operations coming under the control of the engineering department which are of very great assistance to it and which are now in general use in the United States. One of these is the mould loft. The art of lofting as it is now generally followed in American aircraft production was, of course, borrowed from the ship-building industry, just about the time all-metal aircraft construction became prevalent. The process consists essentially of laying out the body and wing lines full-scale on the loft floor. Great accuracy in fairing is inherent in the method because of the large scale. It is apparent that with these lines full-scale, shapes can be transferred directly to templates which, in turn, can be used in the shop as guides for cutting sheet metal or for developing laps and holes for the joining of parts. In America, the control of the loft floor is sometimes under engineering and sometimes under the shop, as it serves both. Nevertheless, as it really is a substitute for a drawing, it seems that it should more logically be placed under the control of the engineering department and the trend is this way. In Fig. 6 the preparation of loft drawings on wide aluminium sheet to be used as a working template and as used in the shop of the Boeing Aircraft Company at Seattle is shown. In the Boeing plant, the templates developed from loft drawings constitute the sole means of reference for the shops in the fabrication of parts and in the assembly of parts in the completed bulkhead or beam. All sub-divisions of the shop, whether building tools, fixtures or the manufacture of parts or assemblies, at all times refer to these templates for information such as contour, radii, length, width, bolt size and spacing, rivet size and spacing, baffles and slots. Such a common source of information minimises errors and loss of parts, time and material.

Another adjunct of the engineering department, not perhaps directly involved in the manufacturing methods, is the wind tunnel, several of which are now owned and operated privately by manufacturing concerns. Such a one is the Curtiss Wind Tunnel at the Curtiss Aeroplane Division Buffalo plant of the Curtiss-Wright Corporation, illustrated in Fig. 7, and showing the balance room with its various instruments and equipment.

Still another adjunct of the engineering department is the mockup. American aircraft companies are finding more and more as time goes on that it pays to construct a mockup with great accuracy, as by means of such a mockup designers and draughtsmen can far better visualise complicated cockpit installations and structural clearances than can be done by three-dimensional drawings. Figs. 8, 9 and 10 show respectively, two views of the mockup of the Curtiss-Wright Twenty Transport being constructed at the St. Louis Aeroplane Division plant of the Curtiss-Wright Corporation and the mockups of two types being produced by Sikorsky Aircraft Division of the United Aircraft Corporation. These Sikorsky models are the S-42A and S-43. Although wood, and frequently paper, is used in constructing mockups, in the case of the Curtiss-Wright Transport a steel covered mockup, incorporating a jack to permit obtaining the proper level for ground, taxying, and flying positions, was built. A further extension of the mockup idea is the complete installation on a board of various systems prior to installation in the aeroplane itself. Such a scheme is shown in Fig. 11 which is a view of the hydraulic system trial installation of the Curtiss-Wright Twenty Transport.

A still further time-saver is the construction and installation on a ground test rig of the complete powerplant installation as illustrated in Figs. 12 and 13. Ground cooling, control functioning and all of the other items frequently requiring long test periods are by this means tried out ahead of time and corrected where necessary, thus speeding up final flight tests and saving costs thereby. The aeroplane is becoming a very complicated piece of equipment and in an industry rapidly advancing both in machine shop practice and scientific research, the less left to chance and whim, the better. The price is perhaps one of reducing complications for users at the cost of increasing complications in the engineering phase of the business. For economy of development and production, the above aids are therefore desirable.

### Planning Department.

One basic function of the planning department, one of the most important divisions of the whole works organisation, is to pass along information taken from engineering drawings and release sheets to the shop. Many supplementary duties devolve upon the planning department, not the least of which, in many factories, is tool design and draughting; tools consisting of templates, patterns, dies, jigs and fixtures. The final stage in the work of the planning department is the preparation of master operations sheets, which in one of their forms serves as an order for purchasing or requisitioning material and which, in addition, specifies each operation of fabrication and inspection, together with the tool and machine to be used in this connection. Fig. 14 is a typical master operation sheet for a part made from a casting purchased on the outside prior to starting through shop operations as listed. It is the duty of the planning department to decide the extent of tooling which the production quantity released by the management warrants constructing. A fine degree of judgment, backed up by general and detailed estimates is necessary to perform this function properly. All persons intimately connected with aircraft works can recall occasions both of under-tooling and over-tooling, either of which greatly increases costs.

Another function of the planning department is to gauge the proper rate of feeding different orders to the shop. Intimate knowledge of machine capacity as well as delivery requirements is necessary properly to perform these duties. Consideration of extra set-up time involved in breaking down total quantities into split shop orders must also be considered. The principal object, in general terms, of this function is to create a condition, as economically as possible, by virtue of which work is pushed through the shop from each prior department rather than pulled through from final assembly. Each subsequent department, feeling the pressure of the parts necessary for it to perform its function piling up behind it, will be impelled to work more efficiently than if it is constantly held up by waiting for parts. One of my American friends has humorously explained what may

occur if the pull, or shortage sheet, method of production urge gains ascendancy. Under such a system, soon every order becomes a rush job and time seems never to be available for detailed study, mature consideration, and logical action. He said, " We have one little trick for handling this situation which may be worth mentioning. Green ' rush ' tickets are used on shop orders considered urgent enough to take priority over routine production and in a few weeks every job in the shop bears a green ticket. We then suddenly shift to red ' rush ' tickets and manage to distinguish a few distinctly urgent jobs until such time as the general colour scheme shifts to the new hue. Two or three colours only will usually suffice to keep the system going as a universal shift to the latest fashion takes practically no time at all!" I judge you all have experience with a condition closely related to this and one which can be obviated by proper planning.

The " conveyor " system of the planning department is the group of despatchers whose job it is to move material, move orders, follow shortages, and in general keep things going through the shop and make sure that the planning department orders are carried out.

FACTORY ORGANISATION.

With all its scientific research; with all its engineering technique; with all its inquiries into customer preference; the aircraft industry in America realises that these would be of no avail except for the loyal co-operation of skilled factory employees who bring the ripe wisdom of experienced craftsmen to the solution of problems not reducible to blueprints.

In Fig. 15 there is shown an air view of the Curtiss-Wright works in Buffalo. The office and engineering department are in front, then the planning department with the factory departments now to be described, lying behind. First it may be of interest to note the nature of the trades represented in an American aircraft factory organisation as indicated by the departmental nomenclature used.

TRADES REPRESENTED IN A TYPICAL MODERN AIRCRAFT FACTORY TOGETHER WITH PERCENTAGES OF PLANT DIRECT LABOUR WHICH THEY CONSTITUTE.

| Trade or department | Percentage |
|---|---|
| Wood workers and pattern makers ... ... | 3 |
| Toolmakers ... ... ... ... ... | 3 |
| Cutting department: Punch press, hydraulic press, shears ... ... ... ... ... | 9 |
| Bench mechanics ... ... ... ... ... | 9 |
| Welders ... ... ... ... ... ... | 4·5 |
| Machine shop ... ... ... ... ... | 14 |
| Foundry and hammer ... ... ... ... | 2 |
| Processing: Plating, heat treat, sand blast ... | 1 |
| Sheet metal ... ... ... ... ... | 15 |
| Sub-Assembly: Panel, fuselage, tail ... ... | 27 |
| Tank ... ... ... ... ... ... | 2·5 |
| Paint and dope ... ... ... ... ... | 3 |
| Cover ... ... ... ... ... ... | 1 |
| Final Assembly ... ... ... ... ... | 6 |
| Total | 100 |

As mentioned heretofore, shop functions can be very simply classified in terms of cutting, forming, fastening, assembling, and finishing. There are some other functions which are perhaps outside of these given, but, in the main, these functions will suffice. Noteworthy in the list of percentages given is the large

proportion of labour involved in the sub-assembly department, that department whose essential duty is fastening. It is apparent from this that any means developed for reducing fastening and joining time will most greatly effect over-all savings.

The arrangement of the Curtiss-Wright Buffalo factory is shown in Fig. 16. It will be noted that a good flow condition maintains with stores at one end working down through shear, punch press, and other cutting departments, tool and machine shop and bench assembly. On the right hand side are the process departments of heat treat and plating and anodising. The parts then progress into the sub-assembly departments, sub-divided into tail surfaces, panels, and fuselages. Coming from the other end are cowl parts, all to meet in the final assembly building, with some passing through paint and dope departments as required. In a separate building adjacent to the other forming departments is the foundry and stack shop where the foundry and drop hammers are located. An experimental department is also located at the engineering end of the building. The shipping room is at the far corner, readily available for receiving parts from sub-assembly which is the condition in which rail shipments are usually made. A system such as this, which permits logical flow of material, greatly facilitates production. Sufficient expansion has recently maintained in the American aircraft industry to permit logical relocations of equipment to such a scheme as illustrated in Fig. 16, correcting the more chaotic condition of several years ago.

No true conveyor system such as the automobile assembly line can be found, nor is it warranted yet. Fig. 17 shows the type of dolly or truck used by Curtiss-Wright for mounting fuselages during their progress through the shop and final assembly. Fig. 18 shows an overhead mono-rail system also used by Curtiss-Wright in their paint shop, while Fig. 19 shows a similar scheme used by Douglas Aircraft Company in their final assembly building.

With the proper functioning of the planning department assuring delivery to shop divisions of drawings, operation sheets, material, and tools, by the aid of which the parts can be economically manufactured, the foreman's job becomes one of supervision and of carrying through such necessary contacts as maintain with despatchers, inspectors, and occasionally with the engineers.

The matter of incentive systems for shop workers is of interest. The plan most widely used in America in the aircraft industry is the so-called bonus system. It is fully realised that this system is not ideal, particularly in an aircraft factory where at most only about two-thirds of the work is susceptible to the application of the bonus incentive method. This fact, in itself, causes some dissatisfaction and, of course, in the quantities so far involved in the industry, plus the fact that many changes enter into construction throughout production, it is extremely difficult properly to set standards. Considerable time study work has, however, been carried out and the scheme is working fairly well. Time study analyses are used both for setting standards and for waste motion elimination. Much discussion of the various profit-sharing arrangements have maintained from time to time, but so far as I am aware, no truly profit sharing schemes are in operation in the American aircraft industry.

### Processes and Methods.

We will now take a trip through a mythical American aircraft works which is a composite of several actual ones. A considerable number of lantern slides have been prepared as representing the best means of conveying to you what you would actually see if you were to make such a trip. Many of your fellow countrymen have paid us the honour of visits in recent years and I may say that similar courtesies have been unfailingly granted to myself and many other Americans who have travelled to England.

At the outset it should be recalled that we have already carried a design through the engineering department and through the planning department where operation sheets and tool designs were decided upon and through the mould loft where

templates were constructed. We thus start through the shop assuming that this information is available to the workmen. The raw material which they are to use has been delivered to them with the other data, either in the form of sheet, bar, or tubing, or again, in the case of outside purchased parts, castings or forgings. Sheet aluminium alloy is treated in the storeroom in the linoil bath as illustrated in Fig. 20 to protect the surface during fabrication. Forgings, many of which were previously described are obtained from the outside by practically all American aircraft companies. The process of their fabrication is fairly well standardised as illustrated in Fig. 21, where a steel landing gear fork is being forged on a steam drop hammer.

*Cutting.*—The first shop operations to be performed, therefore, are those of cutting. Practically all of the standard means of cutting are used in all factories. These are the oxy-acetylene torch, used both for cutting parts and tool steel (the latter, illustrated in Fig. 22, showing the operation at the Lockheed Aircraft Corporation plant); the nibbler; the saw; and the uni-shears. One form of shear, the Northill shear, which has been found very useful in the Curtiss-Wright St. Louis plant is illustrated in Fig. 23, while in Fig. 24 is shown a large eighteen-foot power shear used extensively in making initial cuts of sheet aluminium alloy. In Fig. 25 is illustrated a cutter used at the Curtiss-Wright St. Louis plant which is based on the wood router used with a template. Another variation provides for a movable arm with the work remaining stationary during the operation. Used with a template, this provides a very rapid means of accurately cutting a number of sheets together. Figs. 26 and 27 show this unit as developed by Lockheed, where a large proportion of sheet duralumin used is so cut.

Perhaps the most typical of the cutting mehods so far developed and peculiar to American practice is cutting on the hydraulic press as illustrated in Fig. 28. This method uses a blanking die in conjunction with a mass of confined rubber in the operating head. The press is quick and economical provided work is planned well in order to keep this expensive piece of equipment in constant operation. This is achieved in the case of the Curtiss-Wright Buffalo press illustrated by using three feeding tables, alternatively run under the head by means of rollers. A press utilising electric control for conveying the set-up parts ready to be sheared is used by Douglas. In Fig. 29 a gang-punch in the plant of the Bell Aircraft Corporation in Buffalo, operated on a power brake, is set up for punching stringer holes. This method is very rapid and economical where a great number of parts having equally spaced holes susceptible of use with one set-up are involved; or, in the case of specially spaced holes, where the production order quantity is extensive. Fig. 30 shows a battery of punch presses operated in the conventional manner with die blocks. In Fig. 31, a battery of drills, usually used in conjunction with drill jigs, is shown.

*Forming.*—Next let us consider operations of forming which are of such extreme importance in fabribating metal monocoque structures. First there is the power brake, a standard tool well known to all, which can be used in making simple bends in stringers or in like parts.

Of particular interest, however, is the method which again makes use of the hydraulic press. Such a press, used by the Curtiss-Wright Buffalo plant is illustrated in Fig. 32 and has a capacity of twenty-five hundred tons. Its height is twenty feet, the bed and platen are over six feet from front to back, and the over-all length is twelve feet. Maximum opening is fifty-two inches with a stroke of forty-three inches and an over-all weight of seventy-five tons. The machine may alternatively be used, depending upon depth of draw, with a male and female die, sometimes wood, metal covered, and sometimes zinc and lead; or with a female die only, using soft rubber in the head. Fig. 33 shows two large hydraulic presses used by Douglas; one of two thousand tons and the other of five thousand tons capacity. The latter is the largest hydraulic press used in the aircraft industry and has the tremendous over-all weight of four hundred and twenty tons. The platen and bed at the sides are each eight feet by six feet,

and at the ends five and one-half feet by fifteen feet. The Douglas Aircraft Company, who have pioneered the use of the large press for forming as well as for cutting, have developed many ingenious methods of operation, including electric feeding and special die design. Figs. 34 and 35 show the three thousand ton capacity Lockheed press used by that company for forming operations. The most recent type of press developed in the American aircraft industry is that illustrated in Fig. 36, designed by Messrs. Kindelberger and Atwood, of the North American Aviation Company, Inglewood, California. The toggle link arrangement of the press permits higher pressures with less initial force than is required under the standard type of hydraulic press. An eighteen-inch cylinder here does the work of one sixty inches in diameter. This press has automatic feed tables, hydraulically controlled, and although it is not yet in full production, it will be operating on a production basis shortly. Noteworthy is its construction from standard structural shapes.

In addition to the type of dies mentioned previously, a die made of masonite (a plastic material) has been developed by the Curtiss-Wright St. Louis organisation and others, which can be cheaply manufactured. Such dies have been found to be of sufficient durability to give satisfactory results through production of at least one hundred units. The press used by Curtiss-Wright at St. Louis (Fig. 37) operates in conjunction with this type of die to a great extent (Fig. 38).

The process of forming by use of the drop hammer with lead-zinc dies has, I believe, been far more extensively used in America than elsewhere. This process of forming was started on the West Coast of the United States in about 1928, but after the introduction of all-metal aircraft, its use spread rapidly so that now there are few, if any, American aircraft factories that do not have several drop hammers in constant use. The usual procedure in fabricating dies for use by the drop hammer method is to make a plaster cast of the part to be made; the shape can be developed by means of loft templates, from a mockup of an actual part made by hand, or by any other means which will produce the shape desired. This plaster model is then used as a pattern to make a second plaster cast which, in turn, serves as the pattern to produce a sand mould in which the zinc die is then cast; this is the true die or female portion. The zinc die is then placed in a board frame and filled with molten lead which produces the punch or male die. Such minor grinding is next carried out as may be necessary to give proper metal clearance. During the casting process, bolts which register in corresponding holes in the head of the hammer are cast into the punch. The zinc die is registered on the anvil by casting a lead foundation under and around it. Many ingenious alternative methods of pouring the dies, some involving actual casting on the anvil of the hammer, are used. The following illustrations depict the process:—

Fig. 39 shows a plaster pattern and Fig. 40 shows a zinc die in a box ready for pouring of the lead punch into the die which serves, in this case, as a mould. Fig. 41 shows plaster model and pattern storage, while Fig. 42 illustrates outside die and punch storage. It should be noted that in many instances where sufficient parts for a production lot are run off initially, the dies and punches are immediately re-melted for use in making other dies. Fig. 43 illustrates the touching up of a plaster pattern, and Fig. 44 shows a finished exhaust manifold, all parts of which have been made by this process. The Solar and Ryan Aircraft Companies, both of San Diego, California, have pioneered in the art of exhaust manifold fabrication by this method.

Figs. 45 and 46 show drop hammers of the rope control type used by Boeing and Douglas, respectively. Fig. 47 illustrates dies and punches used by Curtiss-Wright Buffalo plant for the fabrication of exhaust manifolds, while Fig. 48 shows the Curtiss-Wright hammers which are air controlled, as against the more prevalent practice of rope-over-drum control used for the most part on the west coast. Fig. 49 shows a Lockheed hammer with spacer shims of plywood over the die, removed one at a time between hammer blows to allow progressive

forming. In Fig. 50 is shown a variety of parts manufactured by Vultee Aircraft Division of the Aviation Manufacturing Corporation, using the drop hammer process.

There are some parts which are still formed by the bumping process on a pneumatic hammer, although this process is waning. An interesting development of a German process known as stretching has been carried out by the Engineering and Research Corporation, in Washington, D.C., and although not used extensively as yet in America, quite a number of improved machines have been constructed and delivered abroad. This process is suitable for parts having a fairly deep draw with accompanying bend, such as wing tip edges. It is illustrated in Fig. 51. Another development of Mr. Henry Berliner, of the above company, is a sheet metal former which is useful for flanging by a hammer action on dies set in the machine. This machine is shown in Fig. 52 and in operation in Fig. 53.

The original method of forming, using jig blocks and hammering by hand, has very largely disappeared, although occasionally, particularly on experimental work, it is resorted to.

In addition, the draw bench is used quite extensively where long lengths of a part having a given section are desired.

Another very interesting process is the roller-die method used at the Curtiss-Wright St. Louis plant for forming hat-shaped wing stringers and other similar parts. This is illustrated in Figs. 54, 55 and 56, and has been recently described in the American technical press.

Still another method of forming quite extensively used for shallow draws is the so-called crowning method whereby a weighted movable wheel is worked over the material placed on a sand block or rubber, as illustrated in Fig. 57.

*Machine Shop Practice.*—Although a separate heading is given to this item, it nevertheless, in general, is a sub-division of forming, although shape is obtained by cutting on standard machine shop tools rather than by true forming. Machine shops in America are naturally equipped with much the same standard tools as those in England, including all varieties of lathes, millers, drill presses, automatics, grinders, planers, etc. In one or two plants in America, the high precision Swiss jig boring machine, illustrated in Fig. 58, is used in order to obtain the great accuracy necessary for certain jigs. This machine is operated in a room in which uniform temperature is maintained so that the finest precision may be obtained. Fig. 58 and those immediately following are from the Curtiss-Wright Buffalo plant. Fig. 59 illustrates several small jigs used principally as boring and milling fixtures. Fig. 60 shows the set-up for a jigged milling operation on a landing gear, and Fig. 61 illustrates a horizontal grinder used in getting the high degree of accuracy necessary in an oleo strut. Fig. 62 depicts an interesting milling set-up known in the Curtiss-Wright St. Louis factory as the " constellation " miller. By this device, the boring and facing operations on the ends of the wing stringer attachment fittings which come together at a great number of angles can be accomplished. Fig. 63 illustrates an air operated tube bender which utilises the principle of a following ball to prevent crushing of the tubing as the bending operation around a form proceeds.

*Fastening.*—We now come to the general sub-division of shop functions which has to do with fastening together parts elsewhere cut and formed. The broad headings under which fastening operations may be divided are welding and riveting, each having within itself several variations. In Fig. 64 a type of tank used by Curtiss-Wright is shown and in which fairly heavy gauge aluminium is used, welded together at the seams. This particular tank is constructed without baffles. Another type of tank is that illustrated in Fig. 65 which uses a riveted-up baffle assembly with a riveted and welded cover. This type of tank is also made of aluminium. In America, the use of welded aluminium tanks and riveted aluminium alloy tanks finds about equal place in the industry. The use of tanks

integral with the structure of the aeroplane is favoured by some companies, notably Consolidated Aircraft Company, Curtiss-Wright and Lockheed.

Units of steel, which are usually joined by torch welding, are exhaust manifolds, as illustrated in Fig. 66, and some large built-up fittings such as those used on bombers constructed by the Glenn L. Martin Company, and depicted in Figs. 67 and 68.

Electric spot-welding is finding more and more favour. At present, it is used almost entirely for joining stainless steel parts, as illustrated in Fig. 69, where an ammunition box is being welded by a Curtiss-Wright workman. Application of this process to aluminium alloys is gaining and at present non-structural parts, including cowlings, are so welded in many factories. Fig. 70 illustrates spot-welding in the Douglas plant and Fig. 71 shows the joining of Alclad sheets by spot-welding in the Boeing factory. The completed sheets, which cannot be procured sufficiently long from the mill, will form the outer wing skin of a section of the one hundred and fifty-two foot wing span of the Pan-American Boeing Trans-Atlantic Clipper. It appears that it will be some time before general use of the electric spot-welding method of joining aluminium alloys will be employed for major structures. Progress, however, is being made and the advantages of this method are so apparent that it is likely the process will eventually find substantial use. For the present, however, riveting remains the major method of fastening.

Although rivets are, for the most part, not fabricated in aircraft manufacturing plants, an exception is the case of the Consolidated Aircraft Company, who make their own rivets. The two machines illustrated in Fig. 72 are capable of producing rivets for all their needs. The capacity for each machine is one hundred and seventy-five to two hundred rivets per minute, and the size range is from one-sixteenth inch diameter by one-eighth inch length up to three-eighths inch diameter by three-inch lengh. Any of the stand head shapes can be formed as desired.

Although some hand riveting remains, the greater amount is done by air pressure, squeezing, or impact, with as much done on machines as possible. Fig. 73 illustrates a machine riveter used in America. A gang-riveter, heading eight rivets at once, used for attaching stringers to skin sheets is also used by Curtiss-Wright. Figs. 74 and 75 show the Berliner automatic riveter, which is beginning to find substantial favour in two arrangements, fixed and movable. In this type of machine, the sheets are punched and dimpled against a die in one operation and then riveted in a second operation without moving the work.

Formerly, heat-treated aluminium alloy rivets 17S were extensively used, requiring driving within a half hour of heat treatment time or else by retaining suitable condition of rivets throughout the day by refrigeration. Both of these arrangements were costly and it gradually became the concensus of opinion that A-17S rivets, with only slightly lower strength values, would serve as well, and it is now almost universal practice to use these.

A word should be said at this point on the subject of countersunk rivets. We have, in America, perhaps been behind European and, I believe, English practice in the matter of flush riveting the whole wetted surface of the aeroplane. The leading edge of the wing, about twenty-five per cent. of the chord length aft, has been flush riveted for some time and has passed as general practice so that now I firmly believe as new aeroplanes come out, more and more flush riveting, including the fuselage, will be used. Of the two methods of flush riveting in general use, the press or dimple countersunk method is used where the skin is 0.040 inches thick or less. For thicknesses of 0.050 inches or more, it is usual practice to drill countersink the outer skin. In the case of thin skin on a thicker stringer, it is frequent practice to drill countersink the stringer and press countersink the skin into it. However, as methods improve, thicker and thicker gauges become susceptible to press countersinking with an excellent flush job resulting. Forming the dimple by means of the rivet itself is used by at least one manufac-

turer, apparently successfully. Some figures seem to indicate a cost for flush riveting in production of fifteen to twenty-five per cent. over that when using brazier head rivets. This figure will be reduced to the lower limit above with further concentration on proper riveting tools. This same attention to tools, it should be noted, has reduced all riveting costs tremendously, so that present figures in production are more of the order of two to two and one-half cents a rivet rather than the values previously maintaining and which were of the order of four or five cents a rivet.

Having described fastening methods, I will next show sub-assembly departments in which these methods are used. Fig. 76 illustrates the hull and wing assembly line at Consolidated. The wing centre sections shown in the foreground are first assembled in skeleton form in the upright fixtures, the aluminium alloy skin later being riveted in place. As soon as the assembly of the centre section has been completed to the point where it may be removed from the fixture without fear of distortion or misalignment, it is placed on the horizontal movable fixture shown in the lower left hand corner. Here attachment and control fittings are secured in place, removable leading and trailing edge pieces fitted in and engine mounts and nacelles attached. The hull assemblies shown in the background start into the assembly line in the inverted position by securely aligning the hull bulkheads and completing the bottom assembly first. The second operation consists of turning over the completed hull bottom and finishing the assembly of the hull top side. Hulls shown in the centre of the photograph are ninety per cent. completed and will be water tested by filling each compartment separately and testing for leaks.

Fig. 77 shows the assembly of one of the Boeing Clipper centre sections in which bulkheads of both steel and aluminium alloy are used. Over the centre of the assembly will be noted the massive drill jig which moves on rollers over the entire layout to facilitate accurate construction. Fig. 78 shows the bow of the hull of the Boeing Clipper behind the scaffolding.

In Fig. 79 is shown a method of aligning large sub-assembly fixtures by the transit method, which is in rather general use in America. Fig. 80 illustrates the tail surfaces of the Curtiss-Wright " Hawk " 75, which may be considered quite typical of current practice in America. In the following figures, 81, 82 and 83, various stages in the construction of the stabiliser and aileron jig of this aeroplane are indicated. Fig. 84 shows a welding jig for a Curtiss-Wright engine mount. In America, the use of chrome molybdenum steel engine mounts, formed of tubes welded together, is almost universal. Fig. 85 illustrates a jig set-up for the Curtiss-Wright " Hawk " 75 flap, while Fig. 86 depicts a set-up for auxiliary aerofoil construction. It will be noted that the auxiliary aerofoil is very rigidly mounted at the time the skin is riveted to the casting webs.

Fig. 87 shows a Curtiss-Wright " Hawk " 75 fuselage which again illustrates a typical type of construction for aeroplane fuselages in America. The " z " section bulkheads which are penetrated by bulb angle extrusions may be noted. Although there are other arrangements for the structural members of the fuselage, varying slightly from that shown, it is believed that in general, this structure is eminently satisfactory for the purpose.

Fig. 88 illustrates the fuselage jig for the Curtiss-Wright Twenty Transport, while Figs. 89 and 90 show the Curtiss-Wright " Hawk " 75 fuselage jig; the fuselage, it will be noted, is constructed in two halves, later secured together on a horizontal centre line. The fully assembled fuselage is shown in Fig. 91. Although the welded fuselage is little used in America to-day, it has found suitable application in the case of small civil craft, the training planes such as manufactured by North American Aviation. Fig. 92 shows this North American Trainer fuselage, which has the advantage of readily detachable side fairings by means of which unusually good access to all fuselage installations is afforded. Fig. 93 shows a rather impressive line-up of Douglas fuselages.

Although fuselage construction is quite well standardised in America, wing construction varies from plant to plant. The industry is still feeling its way as regards wing design and it is here, I feel, that additional attention is necessary before a final solution will be found. Fig. 94 shows the wing of the Curtiss-Wright Twenty Transport in process of fabrication. The hat-shaped stringers and their novel method of joining to the single shear web are noteworthy. Figs. 95 through 102 illustrate the wing construction of the North American Trainer. Particular attention is drawn to the small sub-assemblies into which the wing is divided, thus making it possible for only two or three men simultaneously to work at a fixture. As a consequence, they may work with maximum amount of efficiency since no over-crowding exists. Fig. 103 is the centre section of the North American Trainer, shown particularly to illustrate the corrugated construction of structure here used and, as well, the assembly of the tanks and landing gear. A comparable set of views of the wing assembly of the Curtiss-Wright " Hawk " 75 is shown in Figs. 104 through 109. Particular attention is called to the type of fixture used and to the progressive stage of manufacture whereby confusion and interference between workmen is avoided by breaking the assembly down into sub-assemblies, thus leaving only a relatively small amount of work to be performed on the master assembly jig. Fig. 110 shows the centre section of this plane with its tank and landing gear installation. Figs. 111 and 112 are shown to illustrate an alternative type of wing construction wherein the monospar arrangement with leading edge for torsion is used. This is on the Curtiss Y1A-18 Army Attack Plane, and, by reason of this method of construction, the aft portion of the wing may utilise a particularly light construction with fabric covering and one which can be cut at the will of the designer for the installation of fuel tanks, bombs, smoke tanks, etc. It is this type of construction which it is felt might be advantageously used with stainless steel, although in the instance illustrated aluminium alloy is used. In this aeroplane a portion of the leading edge of the wing is sealed off to form an integral fuel tank.

Fig. 113 shows the cowling of the Curtiss-Wright 19 R and the very excellent manner in which it can be opened up for permitting maintenance work on the engine.

*Processing.*—The processing departments consist of plating, heat treating, and finishing. It is not believed that the methods of the first two are particularly different in America from those used in England. The anodic treatment is extensively used as a protective coating for aluminium alloys, and Fig. 114 illustrates a very large anodic treatment tank used by Consolidated. The tanks shown are twenty-two feet long by twenty-four feet wide and seven feet deep, are heated by steam coils and have a combined capacity of twenty-five hundred amperes at fifty volts. Fig. 115 shows an electric heat treat furnace in the Curtiss-Wright plant at Buffalo. An interesting variation of the immersion method of quenching after heat treating is the spray method used at Douglas and North American. A movable booth is rolled to the heat treat furnace and parts after removal from the furnace are placed in the booth on a rack; the doors of the booth are then closed and the spray is shot into the booth through pipes perforated with number fifty drill holes, at 190 pounds pressure. This causes a fog-like spray which accomplishes the quenching function. The advantage of the process is based on the claim that troubles with warpage have been entirely eliminated by its use.

Figs. 116 and 117 illustrate the spray paint booth at Curtiss-Wright in Buffalo. A novel feature incorporated in this booth is the water stream, barely visible at the back of the booth in this picture, into which a slight inward air draught draws excess paint where it is carried to the trough at the bottom, thus giving an atmospheric condition for the workmen which is remarkably free from fumes.

*Final Assembly.*—In the final assembly department all parts fabricated in the shops in the form of assemblies come together for complete installation. With

proper care in sub-assembling, before delivery to final assembly, the amount of work in this department, which formerly reached staggering proportions, has been greatly reduced. There still remain, however, a considerable number of items of work which must be performed here, and Fig. 118 illustrates the advancing final assembly line in the North American Aviation plant. With proper planning so that parts are constantly pushed into the final assembly department, delays and costs due to waiting for parts can be very largely obviated.

*Inspection.*—Little has been said about inspection, although there is no stage of progress of material through the shop where inspection does not take place. This was illustrated on the operation sheet where inspection operations are introduced wherever sufficient new work has been performed on a part to make inspection essential. For steel forgings and many built-up parts, the magnaflux method, so widely used in the aircraft engine manufacturing industry is used in many American aeroplane plants. The X-ray process is favoured by one or two firms, notably Lockheed (Fig. 119), although it has not gained a very wide application as yet.

## Type of Construction.

From time to time in the above discourse, I have indicated the type of construction used and the probable degree of permanence which I believe it will hold. I feel that the fuselage construction used in America is particularly well adapted for its purpose and I think that it is likely to continue as at present designed with only minor changes, for a considerable length of time.

Wing construction, however, I feel to be in a state of flux with strong proponents ready to claim advantages for their particular designs. The stressed skin type using one, two, or more shear webs is perhaps predominant. Many use corrugated skin under a smooth surface. Others seem to favour the monospar type with fabric covering aft of the main beam. Still others favour the use of stainless steel. A few still use the two beam-for-bending structure, with metal covering for shear and torsion as found largely in your country. As mentioned heretofore, there may very well be a place for plastics in wing construction. Insofar as the stressed skin construction is concerned, the system used in the Curtiss-Wright Transport has worked out advantageously from the strength and weight-saving standpoint, and indications of cost economy are present.

Tail construction and control surface construction, as depicted by the various illustrations shown, appear satisfactory although it is possible that tail construction type will follow wing construction.

In the construction of the landing gear, little change is anticipated although it is probable a wider use of magnesium castings, as seen so much in England, and Europe generally, will be found in America in the future.

There seems to be general favour for the welded steel engine mount, as previously mentioned, and although occasionally, built-up aluminium alloy mounts are seen, I am inclined to believe that the chrome molybdenum tube welded mount will continue for some time to come.

In the matter of fuel tank construction, there are just about as many welded tanks as riveted tanks, the latter using duprene or neoprene as a leak preventative. The tendency in the future will, perhaps, be toward the latter, with integral tanks finding a definite place.

The table shows the percentage in cost which each of the major groups of an aeroplane represents, at the present time and in 1929. The points of interest are: The relatively high per cent. of the wing group at present in spite of the elimination of struts and wires; the decreased cost of the fuselage; and the substantial increase in landing gear cost due to the addition of the retractable feature. The difference in the equipment group percentages is, of course, due to the detailed differences in the particular installation.

CHART OF COST DIFFERENCES ON MAJOR ASSEMBLIES OF AN AEROPLANE—1929 VS. 1938.

| Item. | 1929 Tube Fuselage, Wooden Beams, Biplane, Fabric Cover, Fixed Landing Gear. Per cent. | 1938 All-Metal Stressed Skin Monoplane with Retractable Landing Gear. Per cent. | |
|---|---|---|---|
| Wing group ... ... ... | 29.0 | 32.0 | |
| Tail group ... ... ... | 7.0 | 6.5 | |
| Body group ... ... ... (Fuselage, engine mount and cowl) | 18.5 | 13.5 | |
| Landing gear ... ... ... | 7.0 | 15.5 | Retractable |
| Powerplant ... ... ... (Not including engine, including installation, fuel and oil systems) | 15.0 | 16.0 | |
| Equipment group ... ... (Controls, instrument board, seats, and cockpit installations) | 12.5 | 8.0 | |
| Armament installation ... ... | 3.5 | 3.0 | |
| Assembly ... ... ... | 7.5 | 5.5 | |
| Total | 100.0 | 100.0 | |

CONCLUSION.

The following Figs. 120 through 127, show representative American aeroplanes of the present day in the finally assembled form or in flight. They are respectively:—

Douglas DC-2 Transport,
Curtiss-Wright P-36A Army Pursuit,
Boeing " 314 " Clipper on the water and in the air,
Lockheed " 14,"
Curtiss-Wright 19R Trainer,
Curtiss-Wright SBC-3 Navy Scout Bomber,
Curtiss-Wright Y1A-18 Army Attack.

In conclusion, for the sake of added emphasis I will recapitulate certain items. The following are general needs in which no doubt we can all improve:

(*a*) Greater shop experience for drafting personnel,
(*b*) Further consideration and experience aimed at determining best method of wing construction,
(*c*) Careful study of the application of stainless steel and spotwelding to aircraft construction,
(*d*) Further development of riveting tools to lessen labour cost involved in this operation with particular reference to flush riveting.

Those next listed are features which have contributed substantially to economical construction in America:

(*e*) More extensive use of the lofting process of full scale layout,
(*f*) The rather extensive use of forgings, castings and extrusions,
(*g*) Works arrangement developed for proper and logical flow of materials, accompanied by adequate planning and tool design departments,
(*h*) The advantageous use of the hammer and press in cutting and forming operations,

(*i*) Recognition of the necessity, in stressed skin construction, for sub-dividing assemblies into small units on which a few men can work to optimum advantage.

I wish to make grateful acknowledgment to the companies whose names I have repeatedly mentioned throughout the lecture, who have most generously co-operated with me by supplying photographs and, in some cases, brief descriptions of their products and processes.

In final conclusion, I wish to express my hope that the information included in this paper will have been found interesting and, perhaps, some of it, instructive to you who have so patiently listened to its presentation. Its purpose is both to aid the general advancement of aviation by continuing the interchange of ideas and information and, it is hoped, further, to promote the friendship existing between our two great countries.

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## Discussion.

Major T. M. Barlow (*Fellow*): Endorsing the references made to the importance of Anglo-American relations, he said the meeting would prove to be historic, particularly bearing in mind that Great Britain was now receiving American aeroplanes manufactured by the methods described in the paper. If it became necessary to choose an ambassador for aircraft production between the two countries, all who knew Mr. Wright would vote for him. He had been known in this country for many years as an eminent American engineer, he had paid us many visits and he had entertained visitors from this country in America, and there had been a free interchange of knowledge, both aerodynamical and engineering, through his good offices.

Referring to the chart of aeroplane quantity production cost curves in Fig. 1 of the paper, Major Barlow hoped that it would be treated in a very broad manner by any representatives of the Contracts Department of the Air Ministry who might be present, because there were very great differences on interpretation.

One was impressed by the amount of equipment laid down in the American factories for the apparently to date small production. The 3,500-ton presses were really amazing, when we in this country were working normally with presses of 300 and 400 tons, and one could not help feeling that the potential value to the American factories must be very much more than we were led to believe by Mr. Wright's paper.

(*Continued on page* 217.)

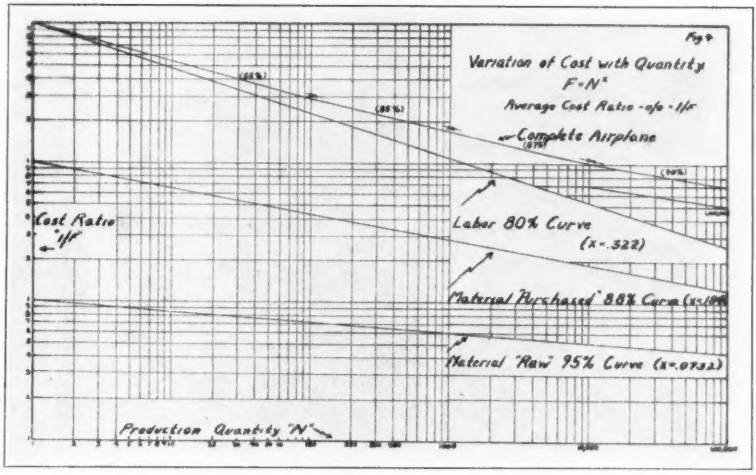


FIG. 1.
*Aeroplane quantity production cost curves.*

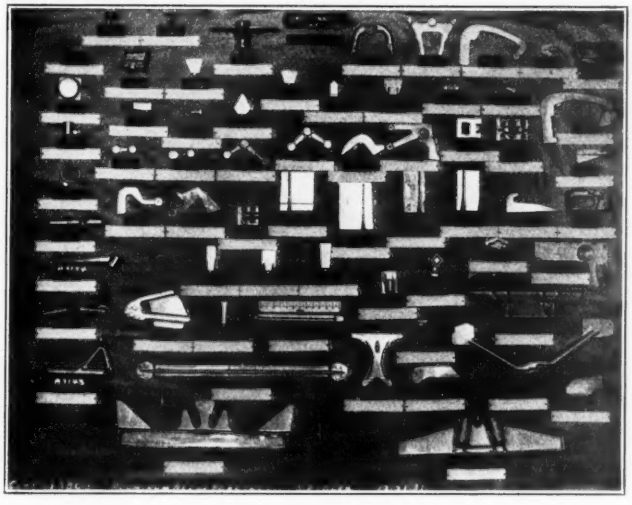

FIG. 2.
*Representative group of aluminium alloy forgings used in a typical American aeroplane.*

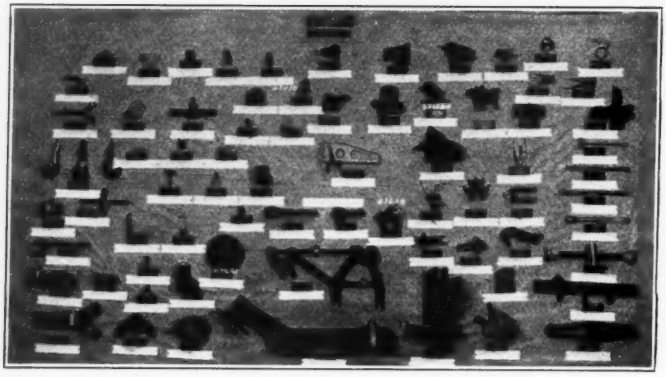

FIG. 3.
*Representative group of steel forgings used in a typical American aeroplane.*

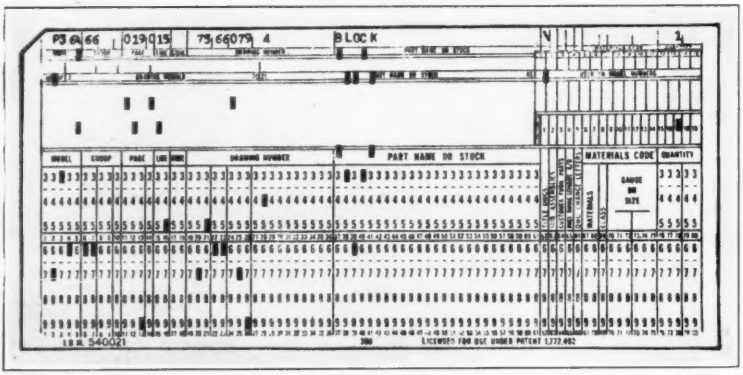


FIG. 4.
*Hollerith accounting machine card adapted to compilation of an aircraft bill of material.*

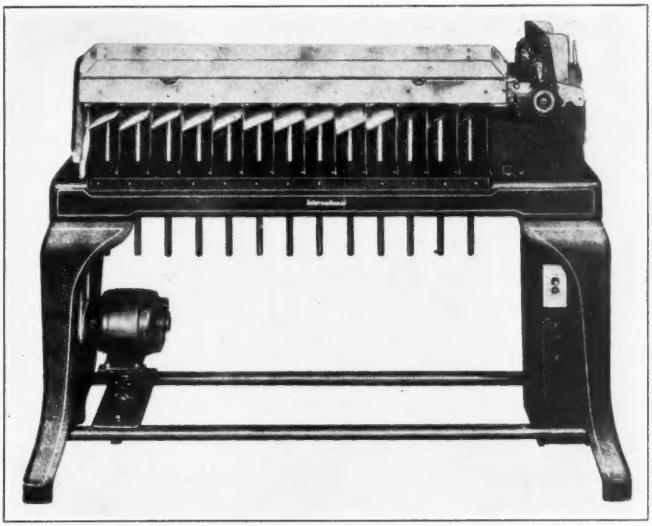

FIG. 5.
*Hollerith automatic card sorting machine.*

FIG. 6.
*Lofting board in use at Boeing plant.*

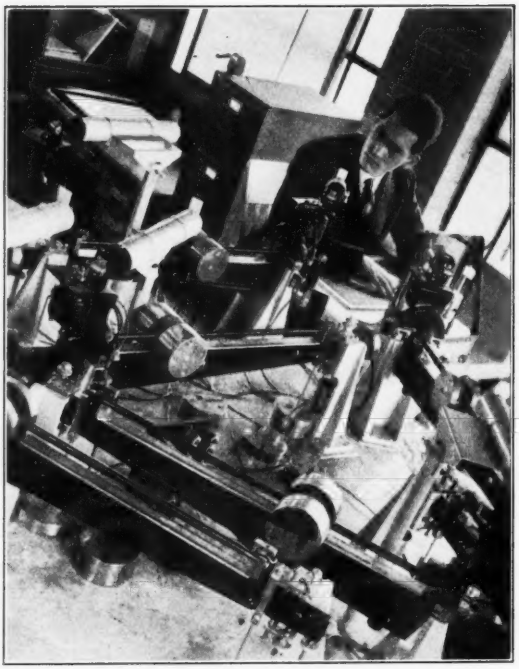

FIG. 7.
*Balance room of Curtiss-Wright Buffalo wind tunnel.*

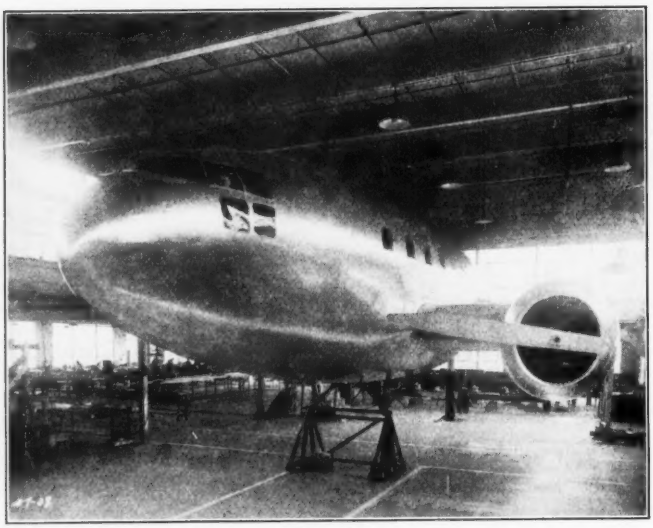

FIG. 8.
*General view of Mockup of Curtiss-Wright 20 Transport at their St. Louis works*

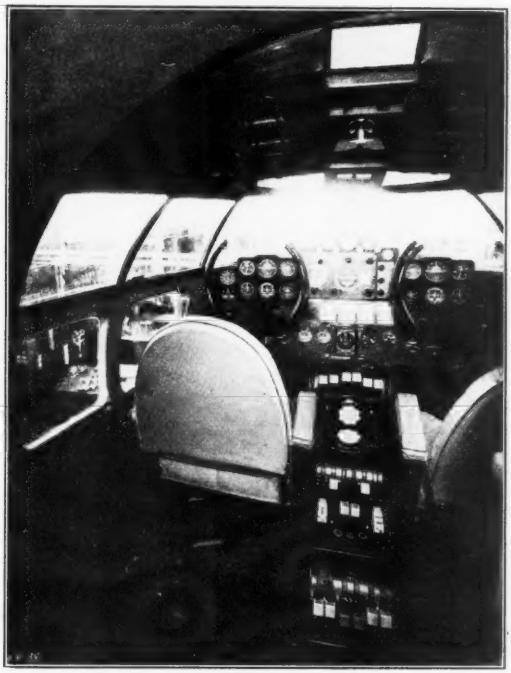

FIG. 9.
*Another view of the Curtiss-Wright 20 Transport showing the cockpit installations.*

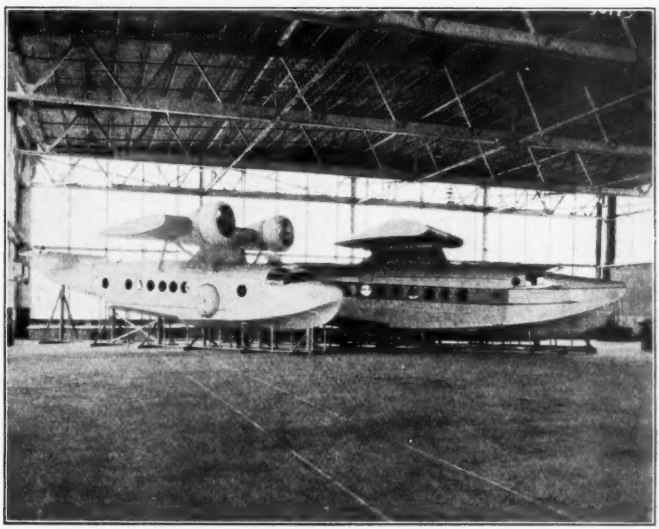

FIG. 10.
*General view of two Sikorsky Mockups in their Bridgeport plant.*

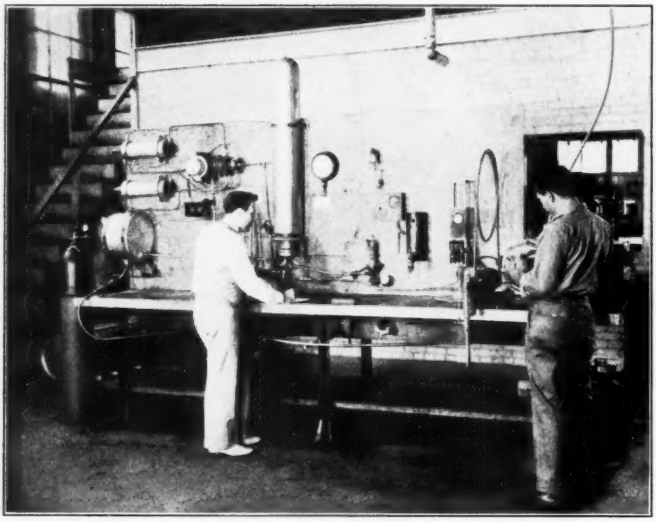

FIG. 11.
*Trial set-up of Curtiss-Wright 20 Transport hydraulic system.*

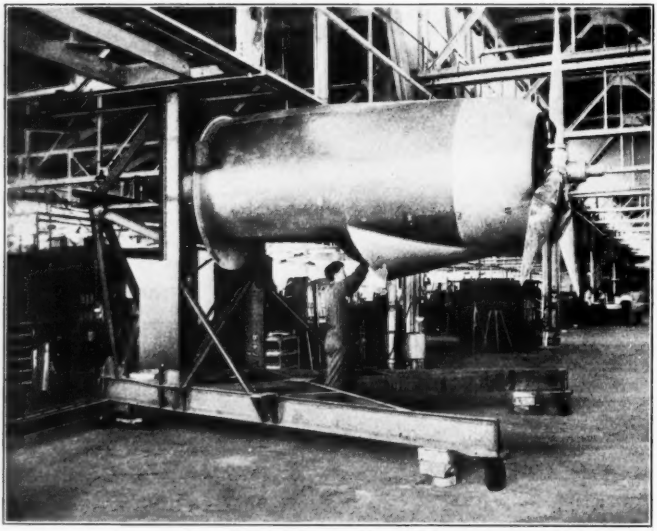

FIG. 12.
*General view of engine ground test stand developed by St. Louis Division of Curtiss-Wright.*

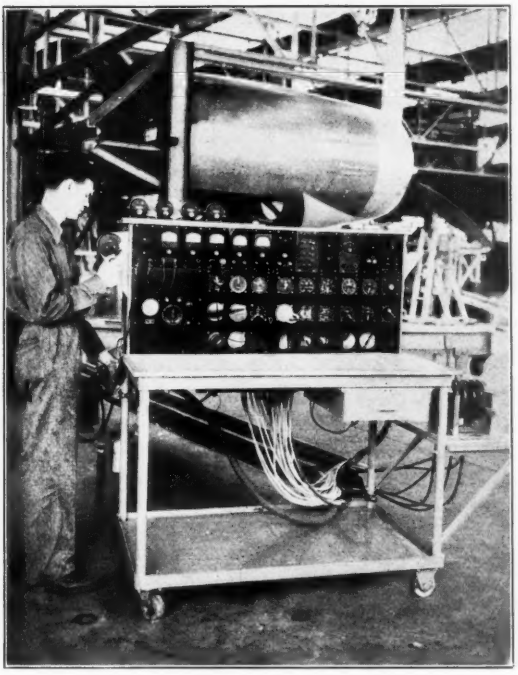

FIG. 13.
*Close-up view of engine ground test stand control board.*

MASTER

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 8-29-38 | | | | | | | | |
| 3 | 9-6-38 | | | | | | | | |
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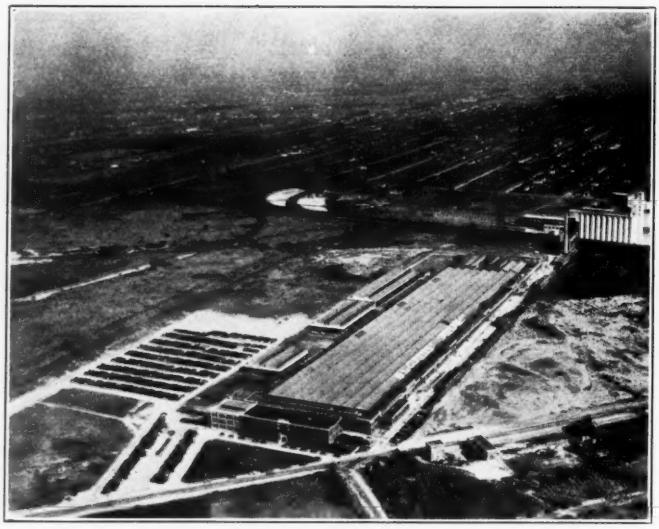

FIG. 15.

*Aerial view of the Buffalo Division Works of the Curtiss-Wright Corporation.*

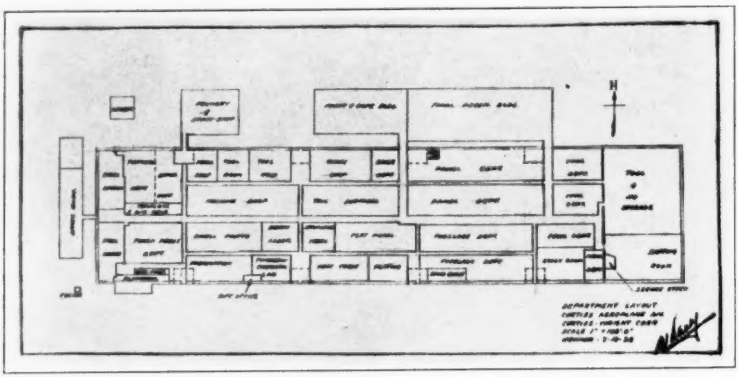

FIG. 16.

*Shop floor layout of the Buffalo Division Works of the Curtiss-Wright Corporation.*

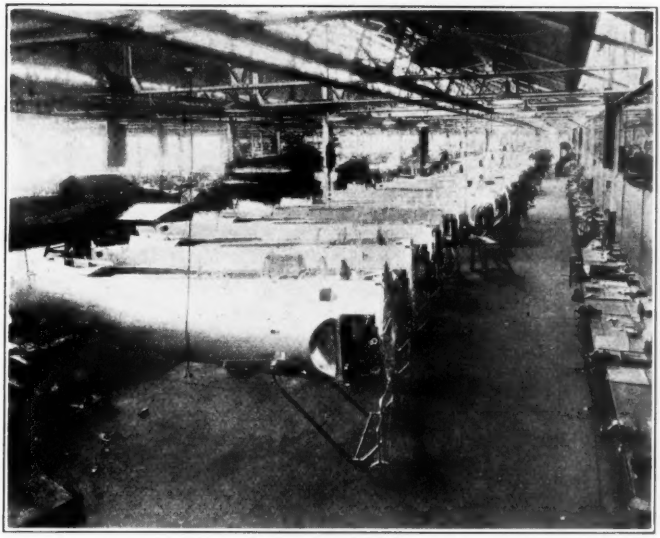

FIG. 17.

*Typical fuselage assembly "line" showing type of dolly or truck used for moving the fuselage through the shop.*

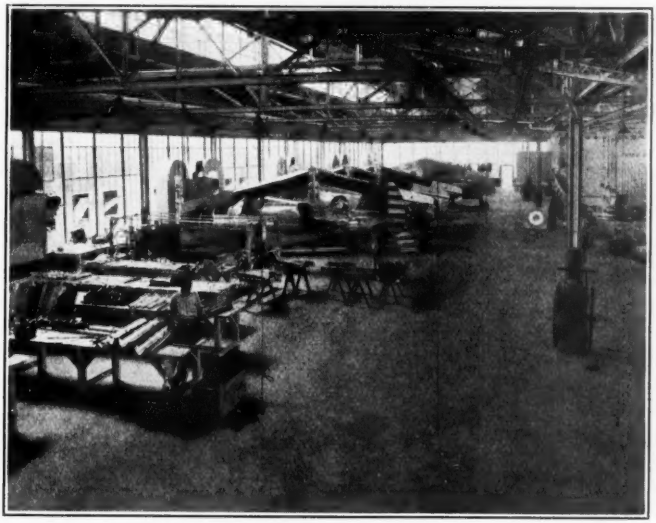

FIG. 18.

*Overhead mono-rail parts conveying system in use at Buffalo works of Curtiss-Wright.*

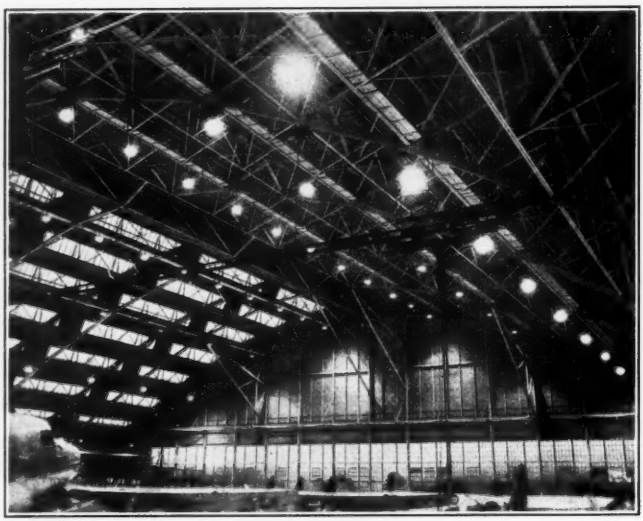

FIG. 19.
*Overhead mono-rail in assembly hall at Douglas Works.*

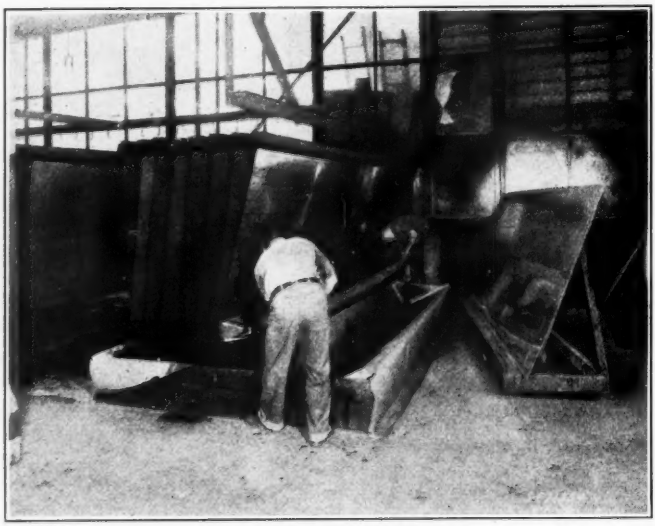

FIG. 20.
*Sheet stock linoil bath at Buffalo Works of Curtiss-Wright.*

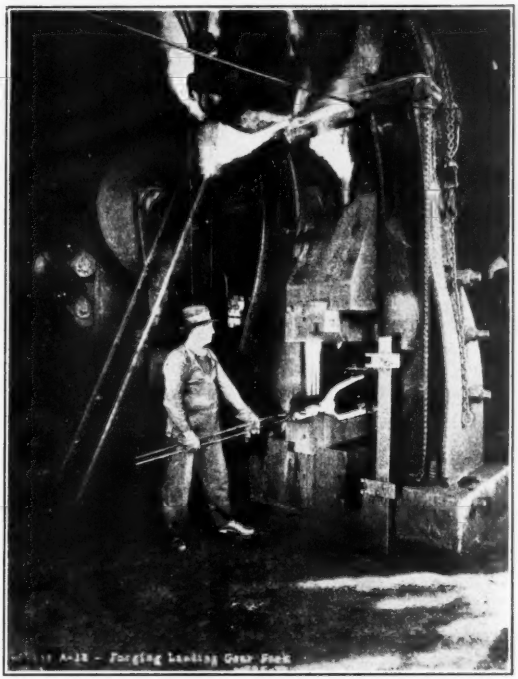

FIG. 21.
*Forging a landing gear fork on a steam hammer at the plant of a vendor specialising in fabrication of large forgings.*

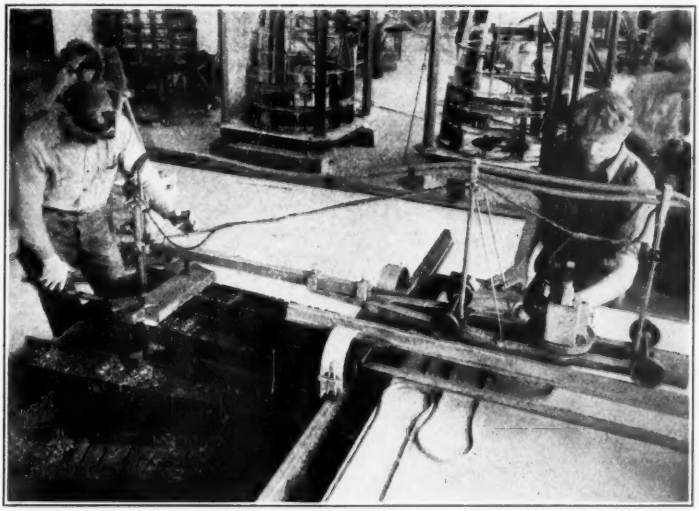

FIG. 22.
*Cutting steel bar stock with an acetylene torch at Lockheed Works.*

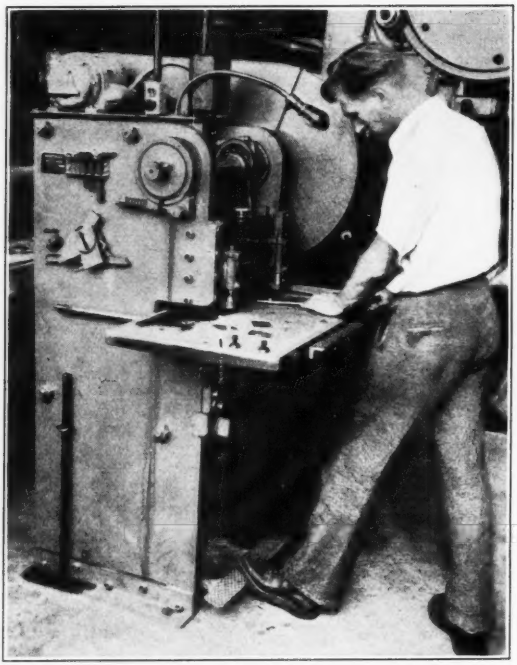

FIG. 23.
*Northill shears as used at St. Louis Works of Curtiss-Wright.*

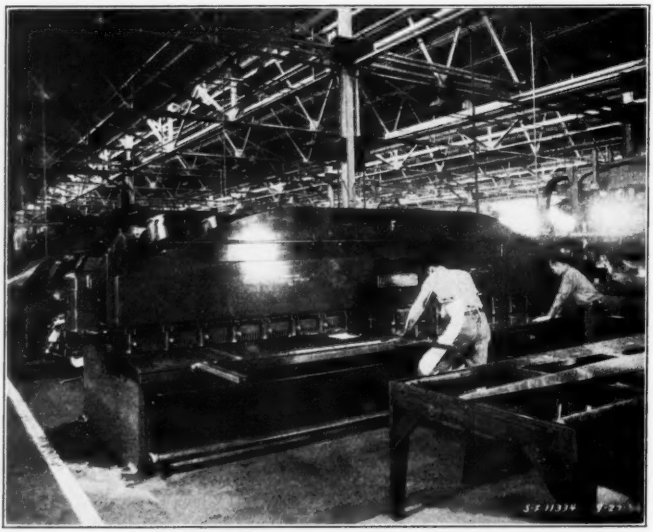

FIG. 24.
*18-foot shears as used at Buffalo Works of Curtiss-Wright.*

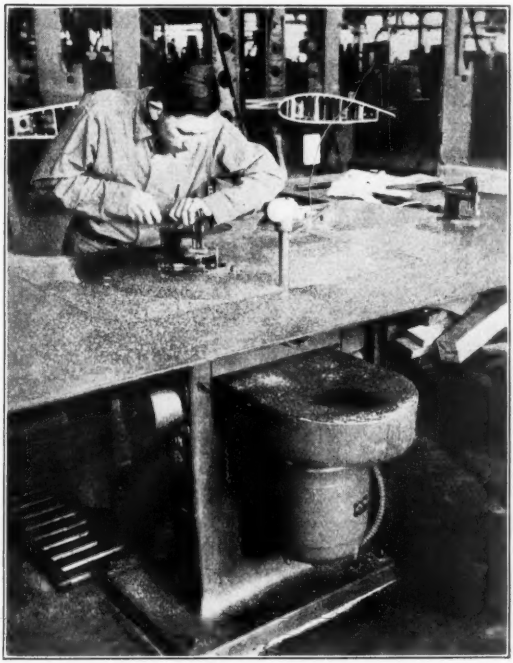

FIG. 25.
*Wood router type metal cutter as used at St. Louis Works of Curtiss-Wright Corp.*

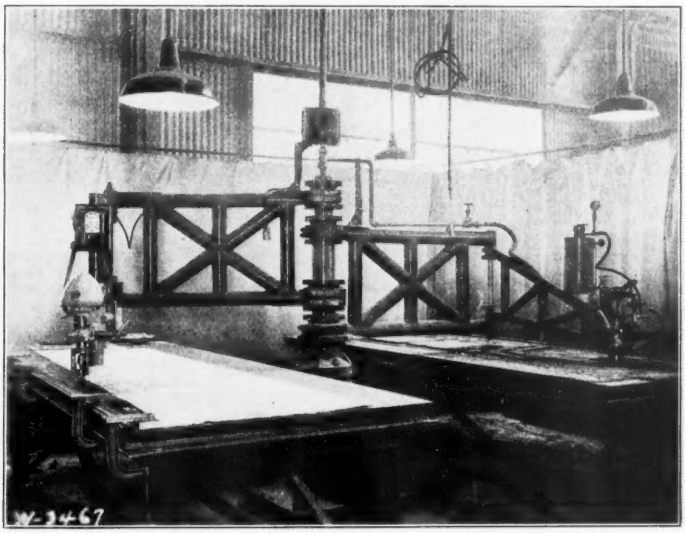


FIG. 26.
*Movable head type router cutter used at Lockheed Works.*

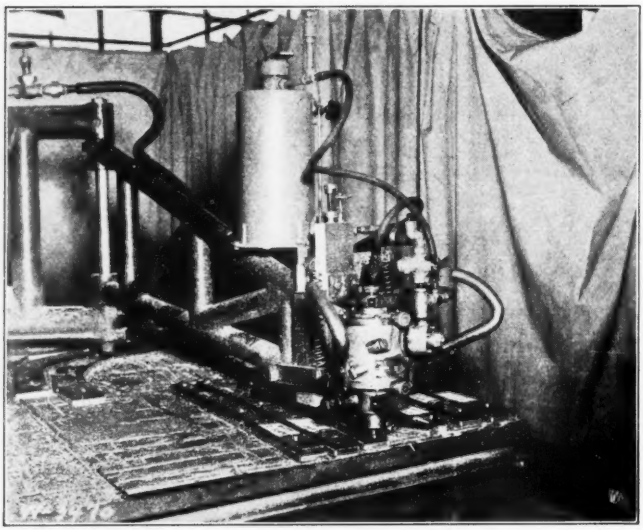

FIG. 27.
*Close-up view of the cutter illustrated in Fig. 26.*

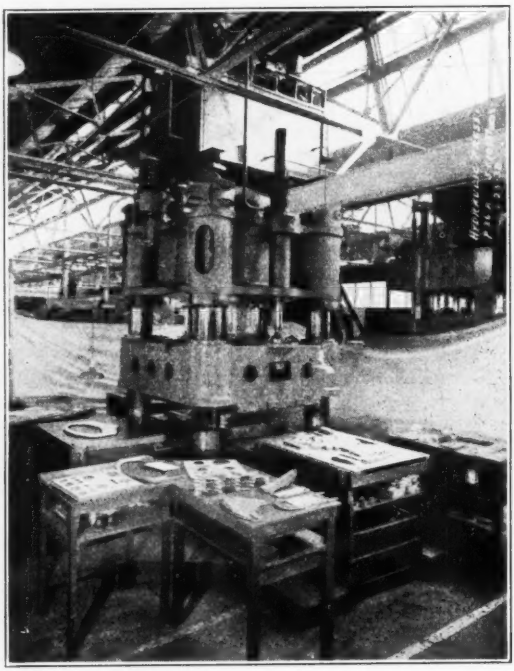

FIG. 28.
*Hydraulic press as used at the Buffalo Works of Curtiss-Wright.*

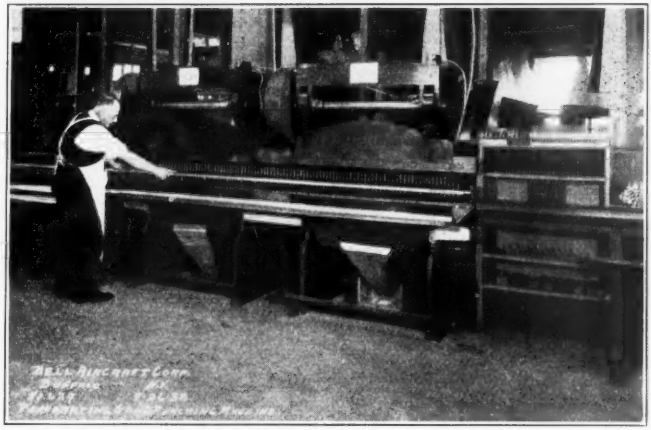


FIG. 29.
*Gang punch as used at Bell Aircraft Company Works.*

FIG. 30.
*Battery of punch presses as used at Buffalo Works of Curtiss-Wright.*

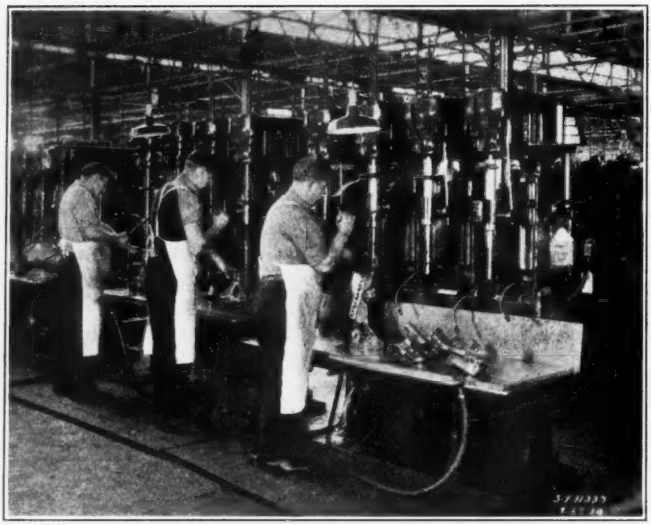

FIG. 31.
*Battery of drill presses as used at Buffalo Works of Curtiss-Wright.*

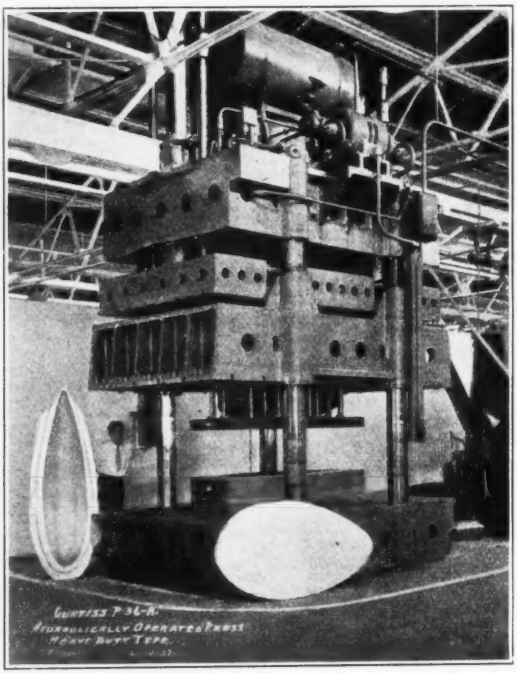


FIG. 32.
*Large hydraulic press as used for forming at Buffalo Works of Curtiss-Wright.*

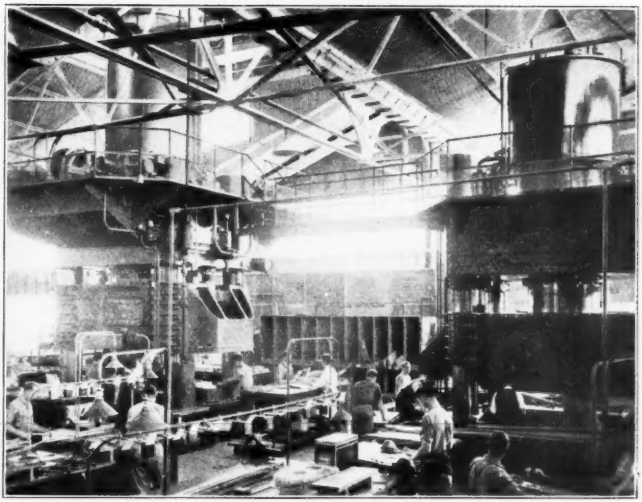

FIG. 33.
*Two extremely large hydraulic presses used for shearing and forming at the Douglas Works.*

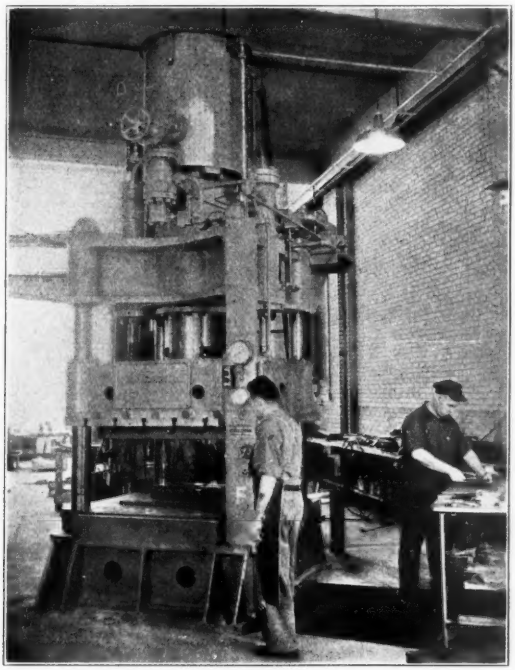

FIG. 34.
*Large hydraulic press as used at Lockheed Works.*

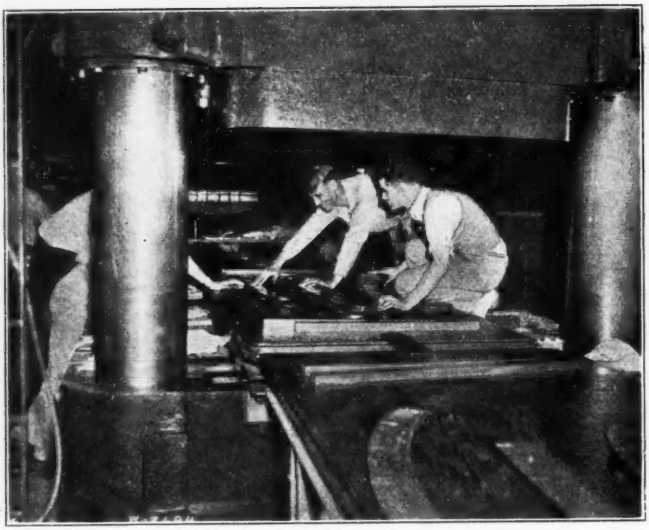

FIG. 35.
*Close-up view of the bed of the press illustrated in Fig. 34.*

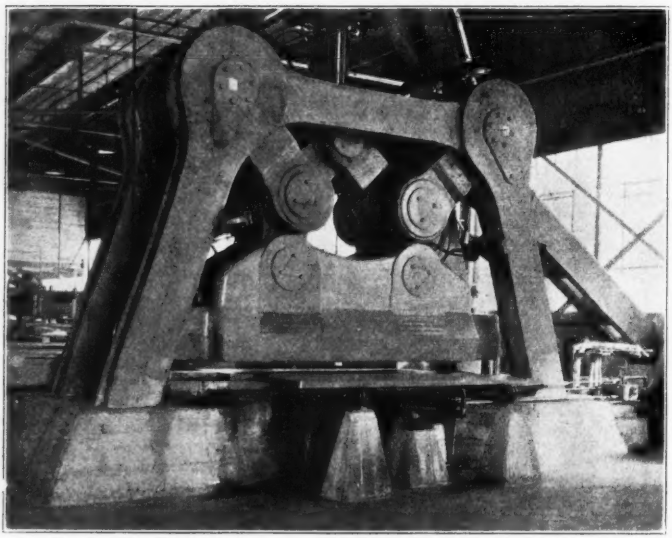

FIG. 36.
*Specially designed toggle type hydraulic press in North American Aviation plant.*

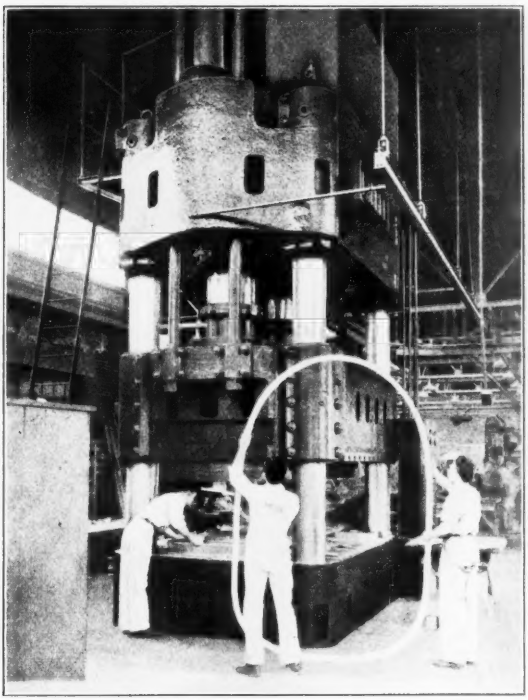

FIG. 37.
*Hydraulic press used at St. Louis Works of Curtiss-Wright.*

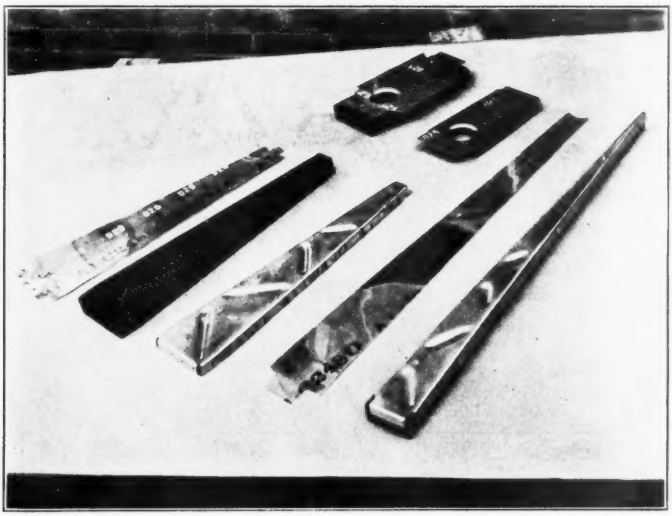

FIG. 38.
*"Masonite" composition dies used by St. Louis Works of Curtiss-Wright in their hydraulic press.*

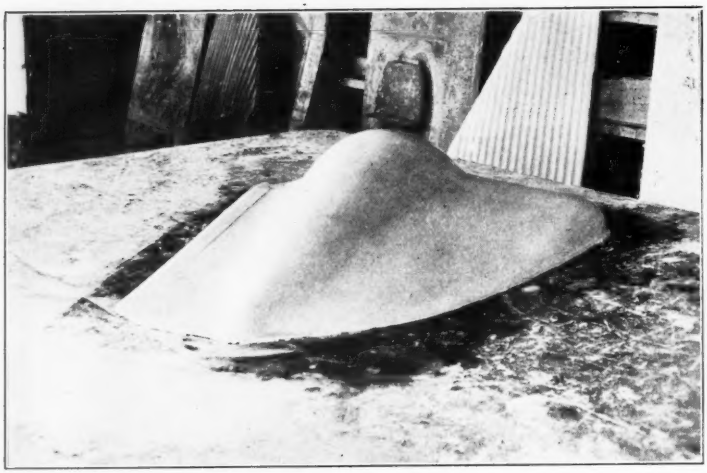

FIG. 39.
*Plaster model for use in casting hydraulic press dies at Vultee Works.*

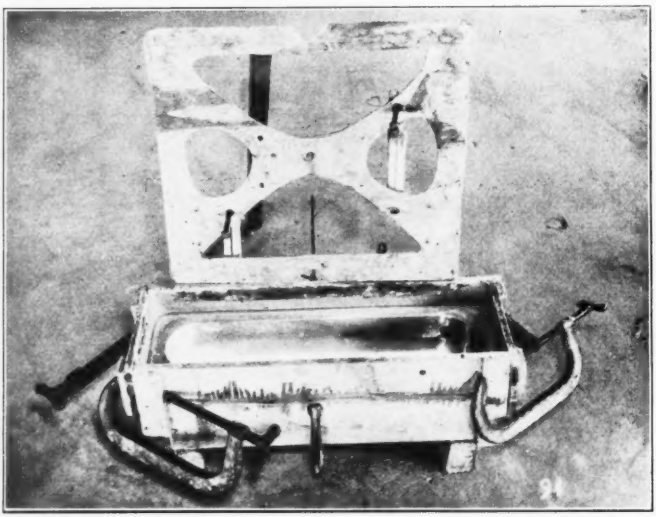

FIG. 40.
*Zinc die fabricated for hydraulic press work at Vultee assembled for pouring lead punch.*

FIG. 41.
*Plaster pattern storage at the Vultee Works.*

FIG. 42.
*Outdoor die and punch storage at Vultee.*

FIG. 43.
*Touching up plaster model of hydraulic press die at Solar Aircraft Works.*

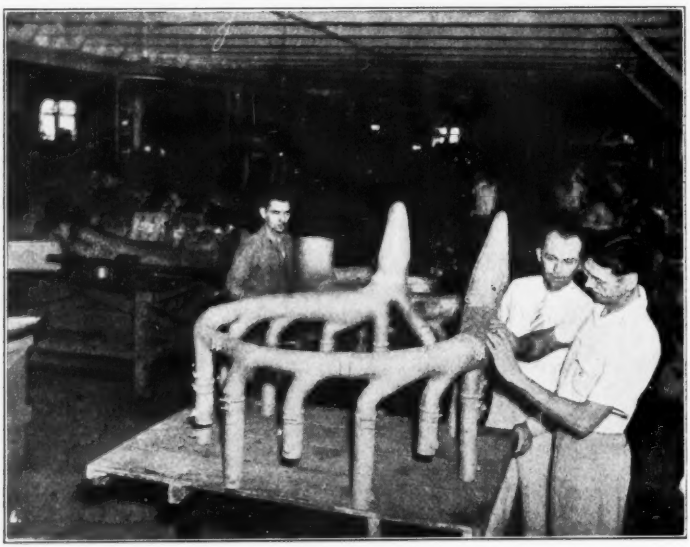

FIG. 44.
*Exhaust manifold manufactured at the Solar Works.*

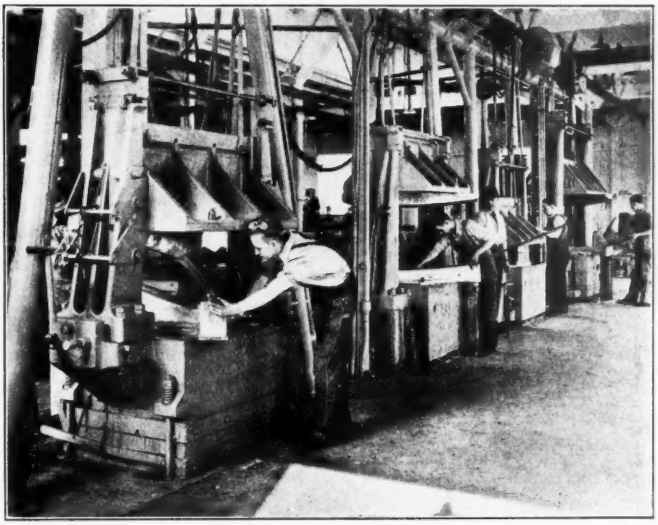

FIG. 45.
*Rope control drop hammers at the Boeing Works.*

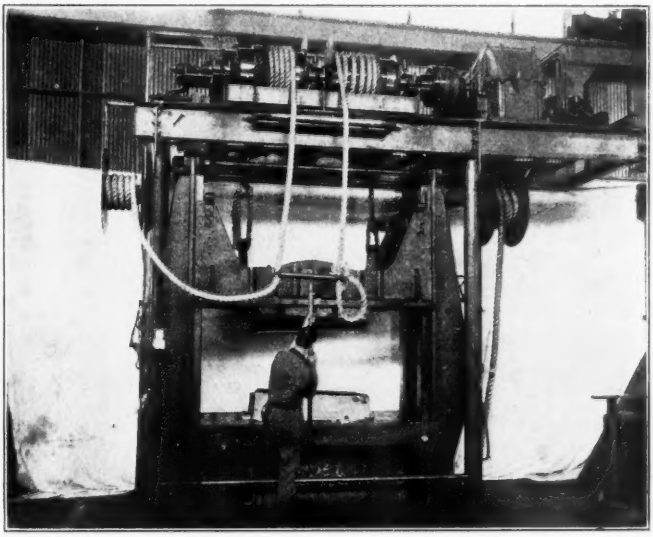

FIG. 46.
*Rope control drop hammer at the Douglas Works.*

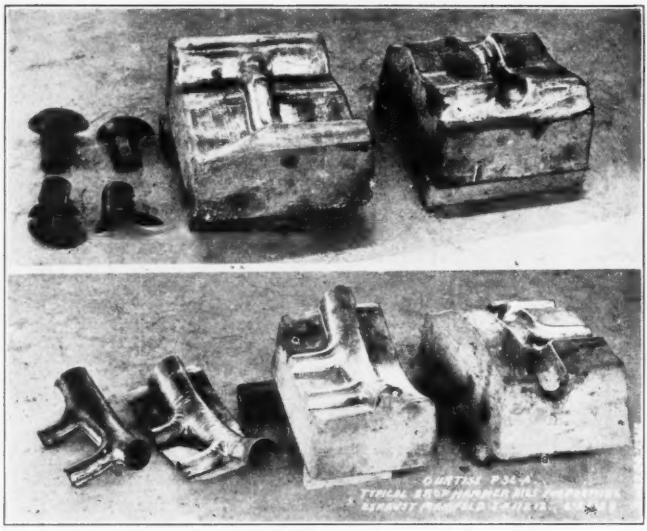

FIG. 47.
*Dies and punches for forming exhaust manifolds at Buffalo Works of Curtiss-Wright.*

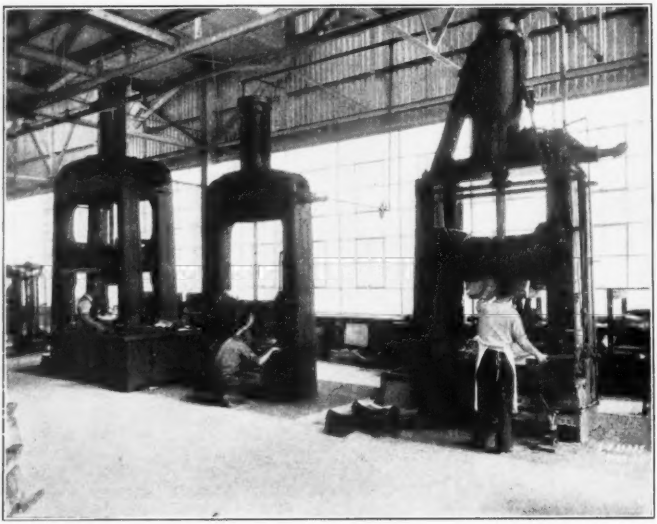

FIG. 48.
*Air control hammers at Buffalo Works of Curtiss-Wright.*

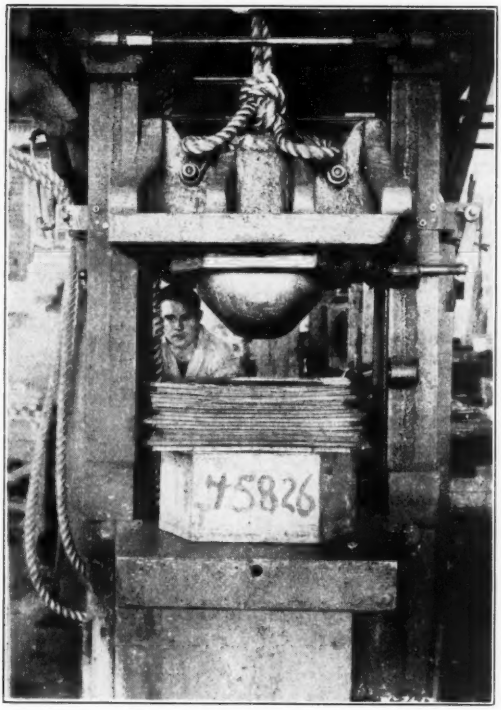


FIG. 49.
*Rope control drop hammer with spacer shims as used at Lockheed Works.*

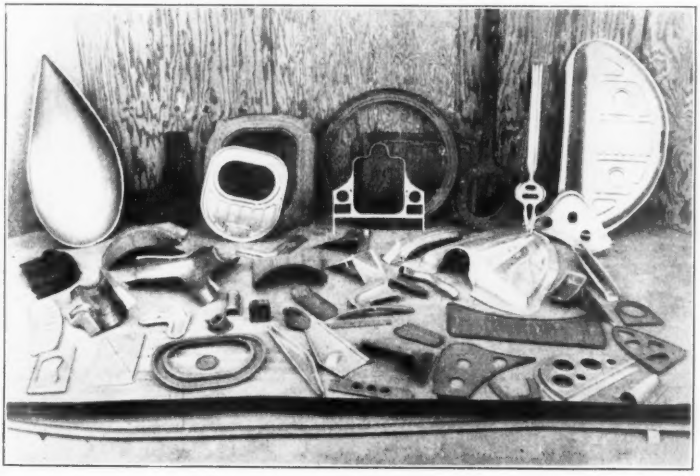

FIG. 50.
*Miscellaneous parts fabricated on the drop hammer at Vultee Works.*

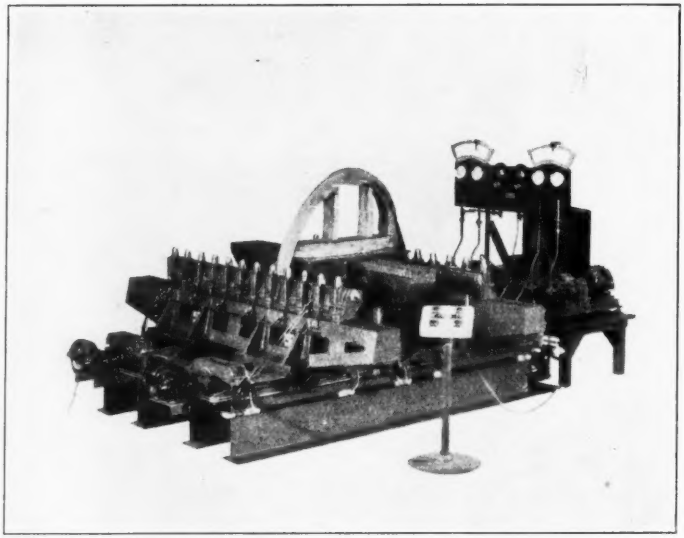

FIG. 51.
*Metal stretcher developed by Engineering and Research Corp.*

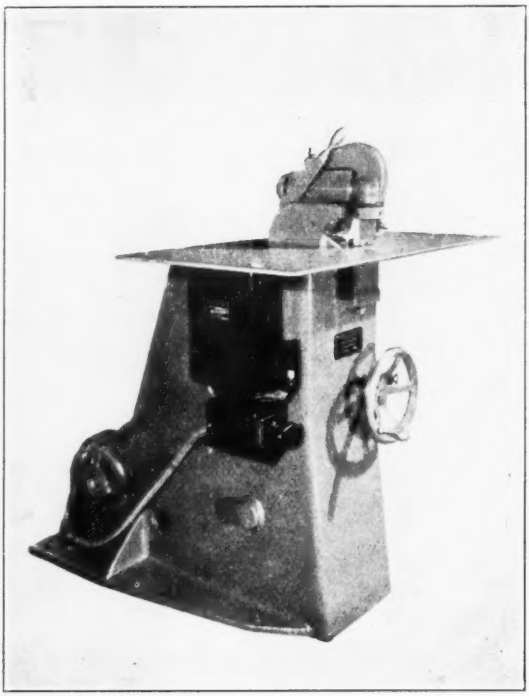

FIG. 52.
*Flanging machine developed by Engineering and Research Corporation.*

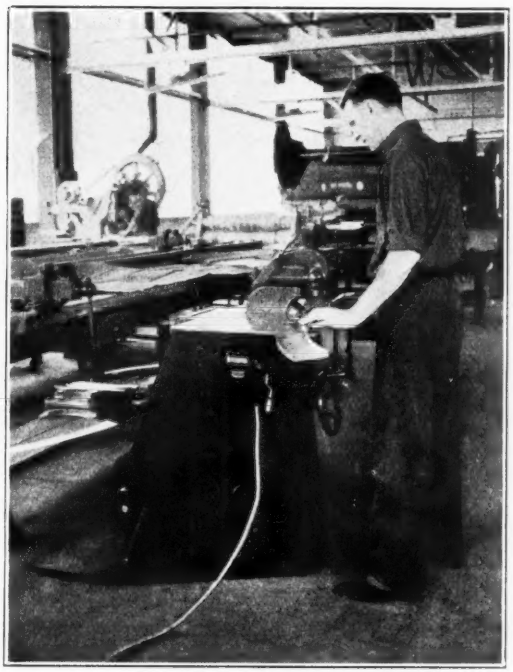

FIG. 53.
*Engineering and Research Corp. flanger in use at St. Louis Works of Curtiss-Wright.*

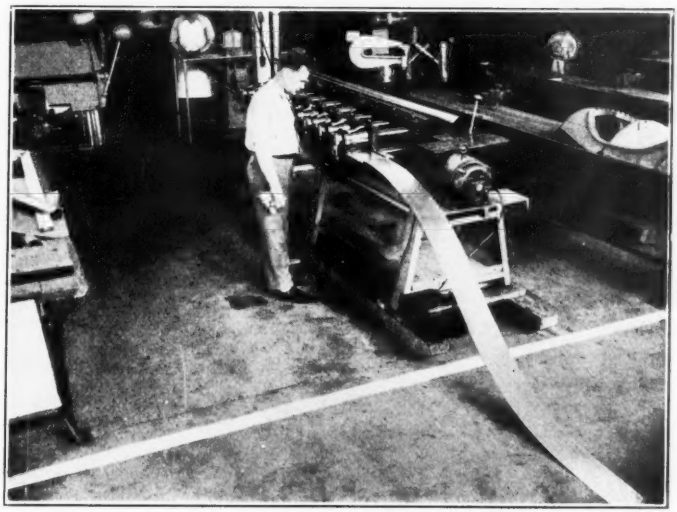

FIG. 54.
*Special rolling mill developed at St. Louis Works of Curtiss-Wright.*

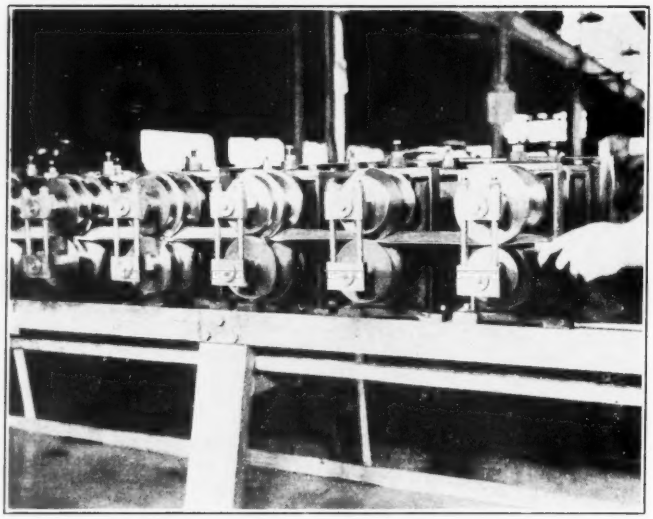

FIG. 55.
*A close-up view of the rollers of the mill illustrated in Fig.* 54.

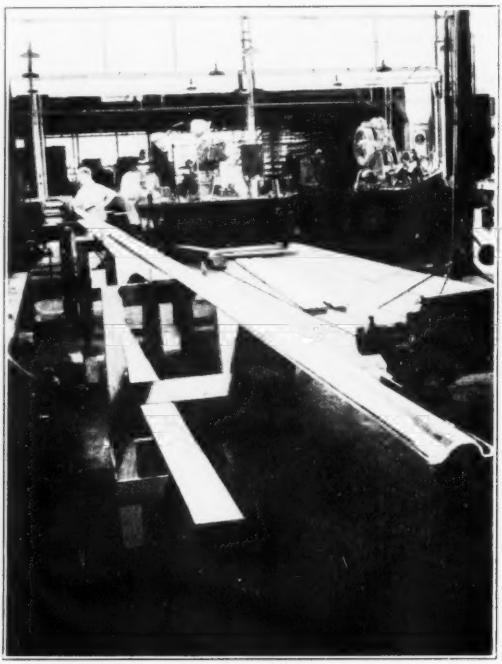

FIG. 56.
*Another view of the rolling mill illustrated in Fig.* 54, *showing a completed length of material.*

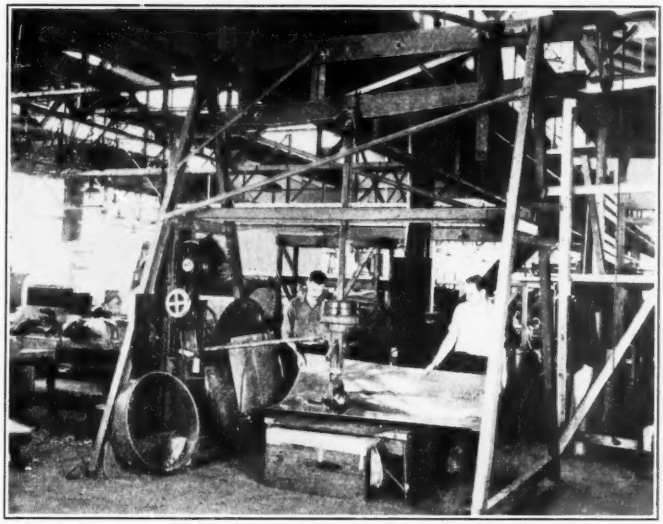

FIG. 57.
*Specially developed crowning machine of St. Louis Works of Curtiss-Wright Corporation.*

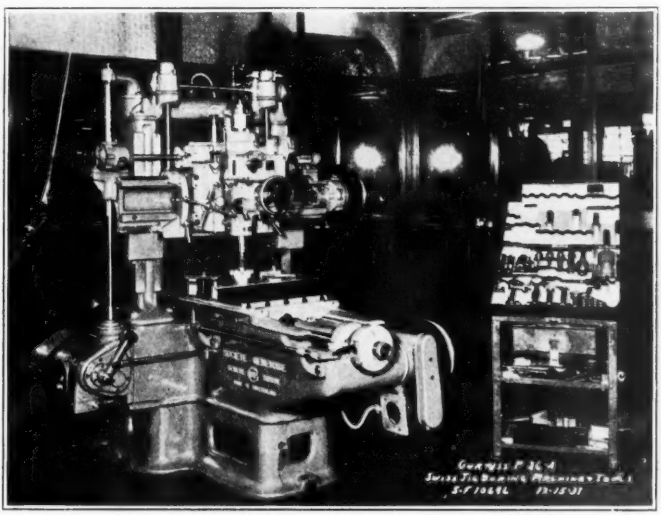

FIG. 58.
*Swiss jig-boring machine used at Buffalo plant of Curtiss-Wright.*

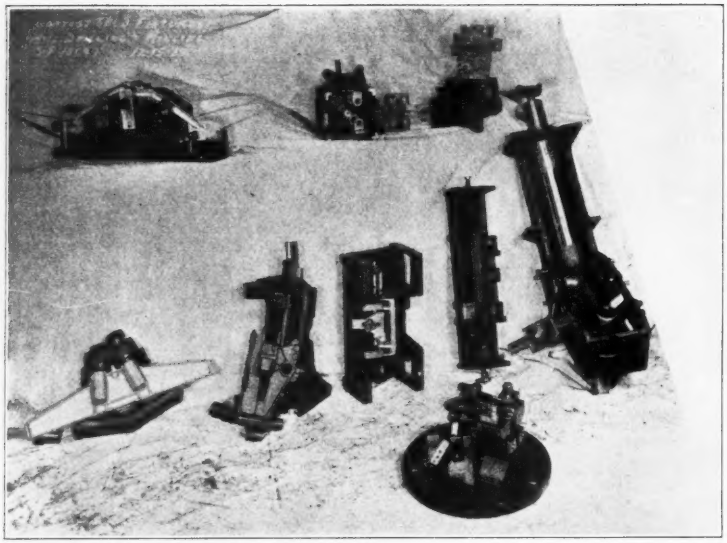

FIG. 59.
*Boring and milling jigs used at Buffalo plant of Curtiss-Wright.*

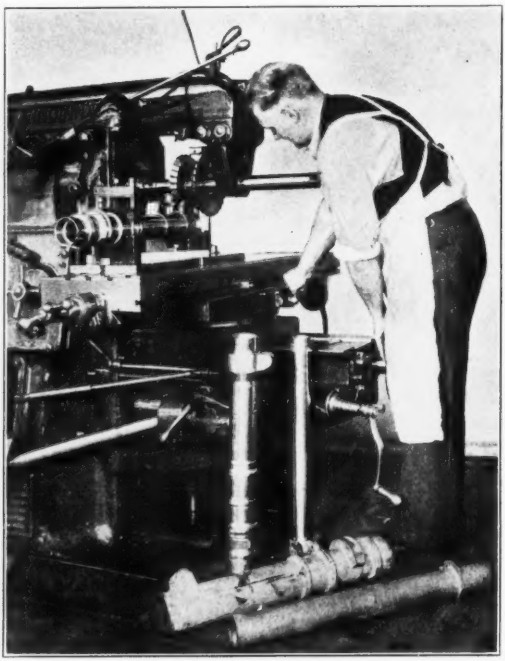

FIG. 60.
*Milling landing gear parts at Buffalo plant of Curtiss-Wright.*

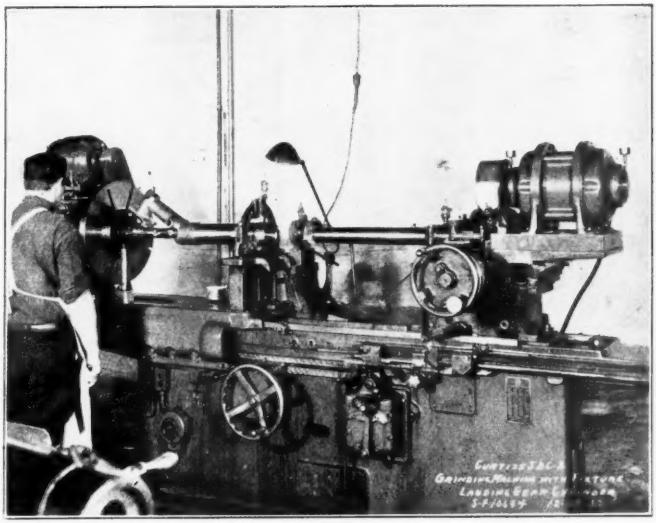

FIG. 61.
*Grinding oleo strut at Buffalo plant of Curtiss-Wright.*

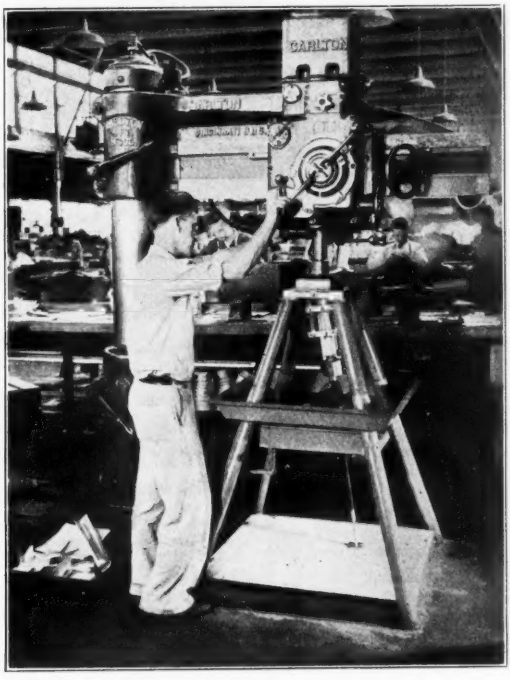


FIG. 62.
*Specially developed "Constellation" miller and drill in use at St. Louis Works of Curtiss-Wright.*

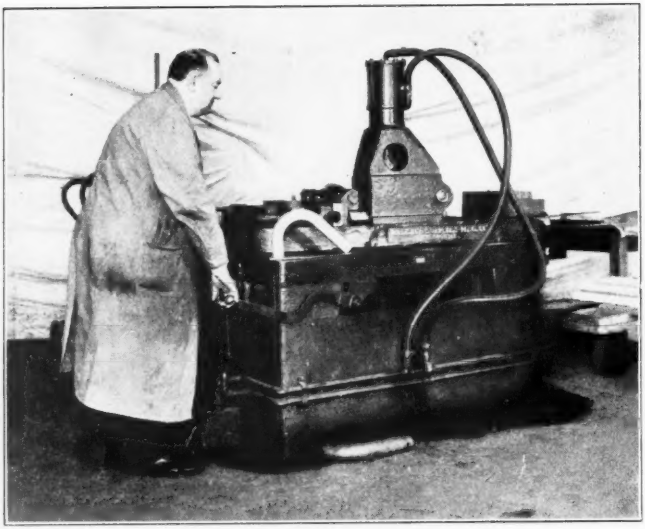

FIG 63.
*A pneumatic tube bender used at Buffalo Works of Curtiss-Wright.*

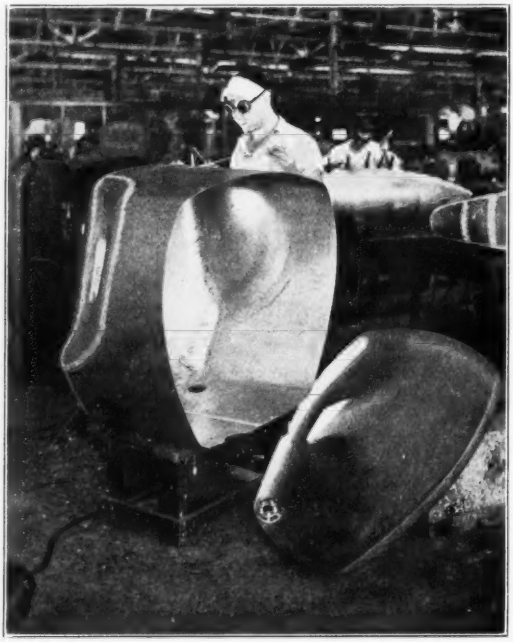

FIG. 64.
*Torch welding aluminium fuel tanks at Buffalo Works of Curtiss-Wright.*

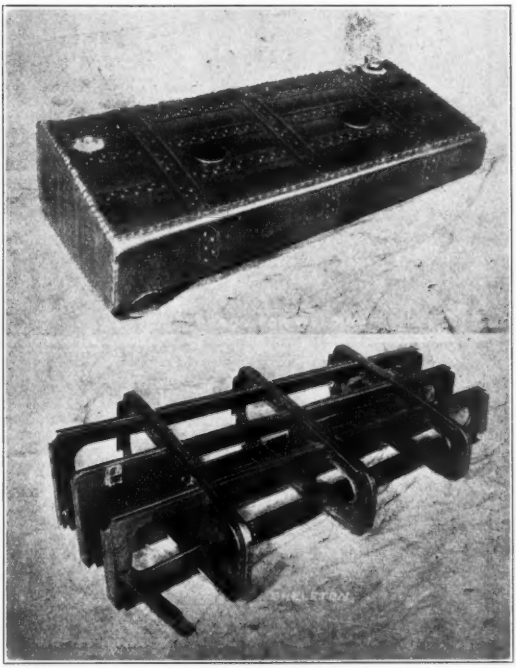

FIG. 65.
*Type of riveted and welded fuel tank and its baffle developed at Buffalo Works of Curtiss-Wright.*

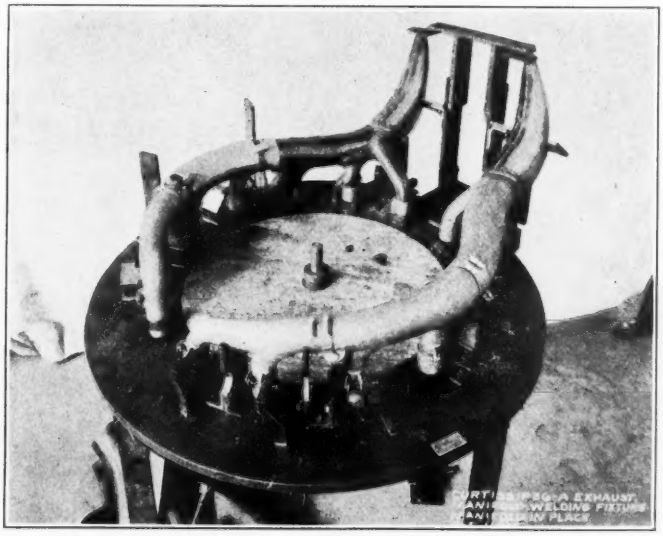

FIG. 66.
*Welded exhaust stack as fabricated at Buffalo Works of Curtiss-Wright.*

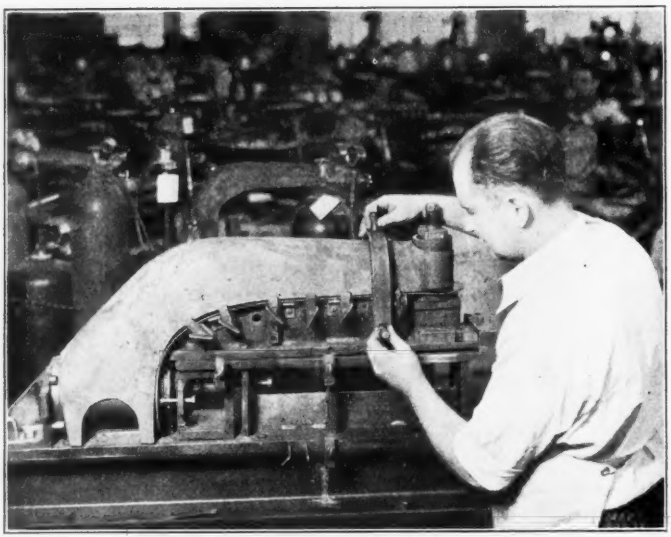

FIG. 67.
*Welded fittings fabricated at the Martin Works.*

FIG. 68.
*Welded landing gear fittings fabricated at the Martin Works.*

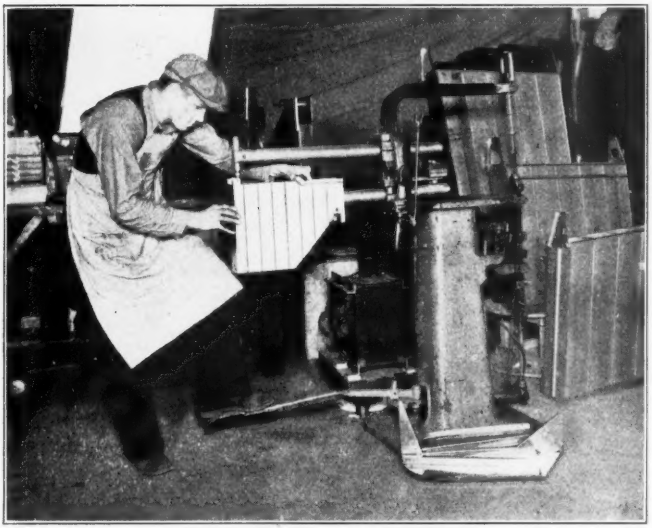

FIG. 69.
*Spot welding a stainless steel ammunition box at the Buffalo Works of Curtiss-Wright.*

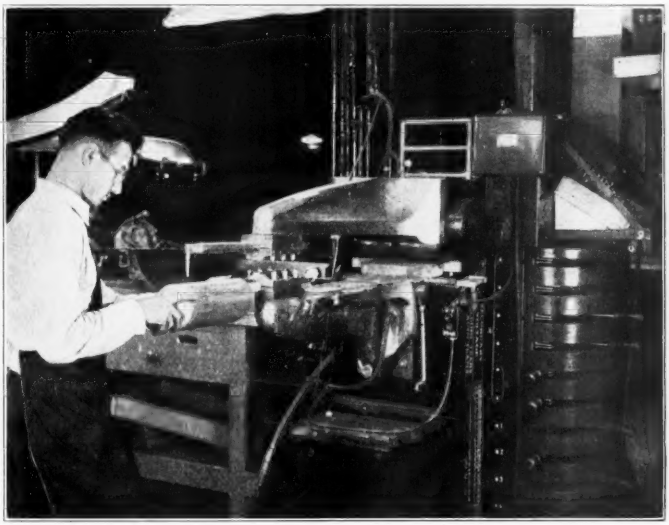

FIG. 70.
*Aluminium alloy spot welding operations at the Douglas Works.*

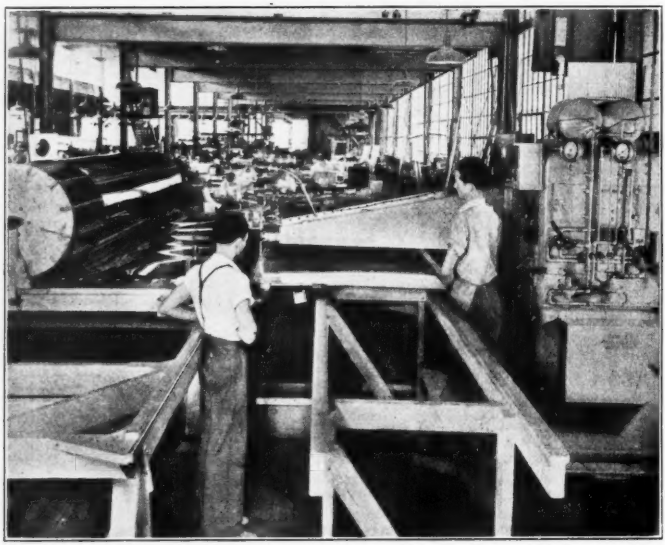

FIG. 71.
*Electric spot welding operations at the Boeing Works.*

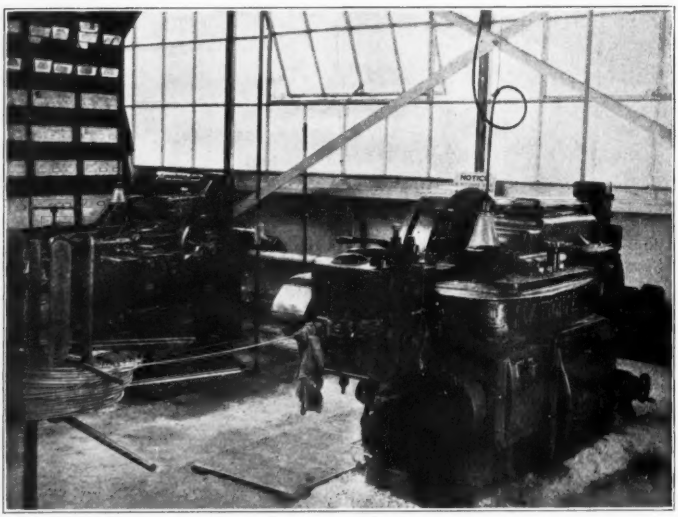

FIG. 72.
*Rivet making machine used at the Consolidated Works.*

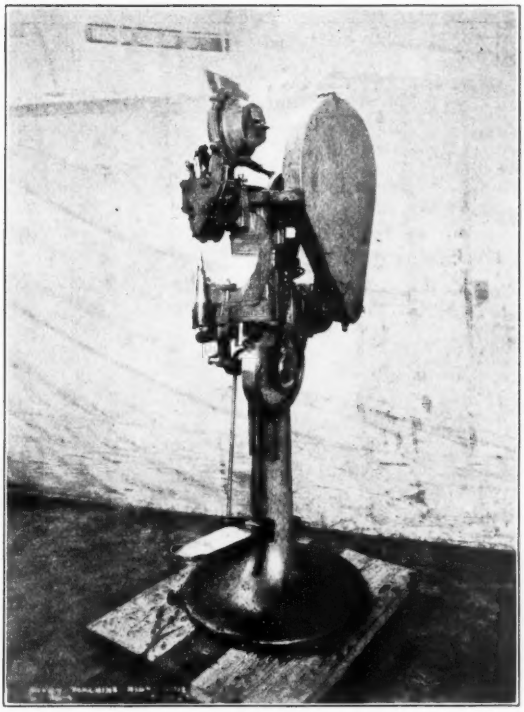

FIG. 73.
*Riveting machine used at Buffalo Works of Curtiss-Wright.*

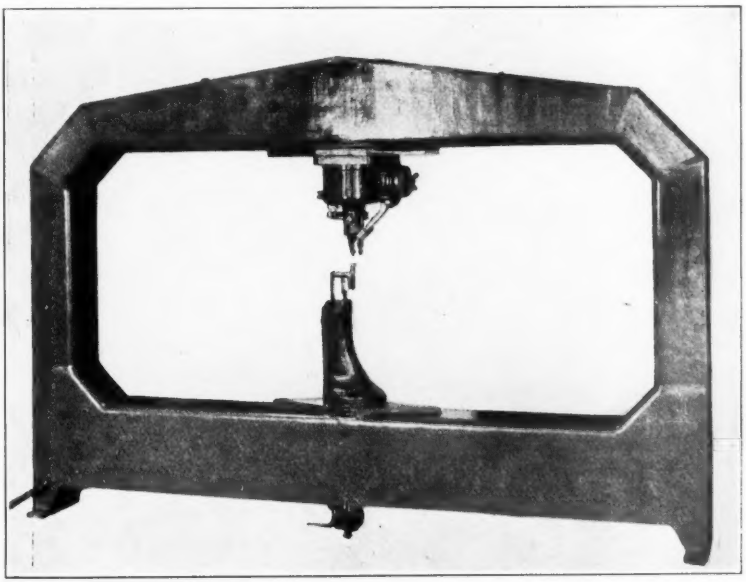

FIG. 74.
*Fixed riveting machine developed by Engineering and Research Corp.*

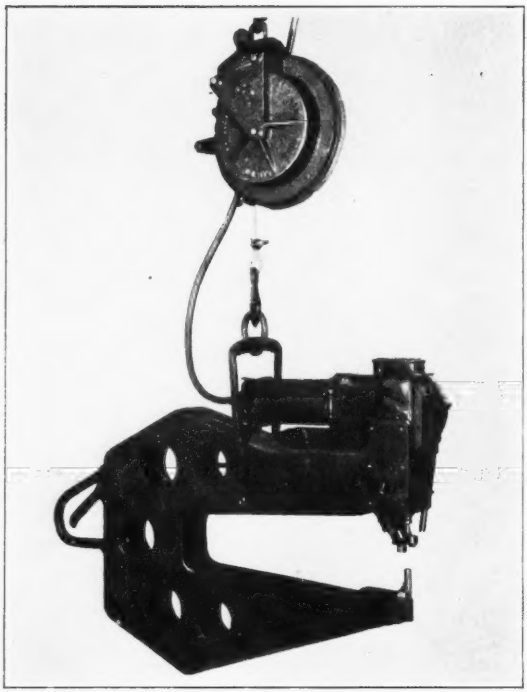

FIG. 75.
*Portable riveting machine developed by Engineering and Research Corp.*

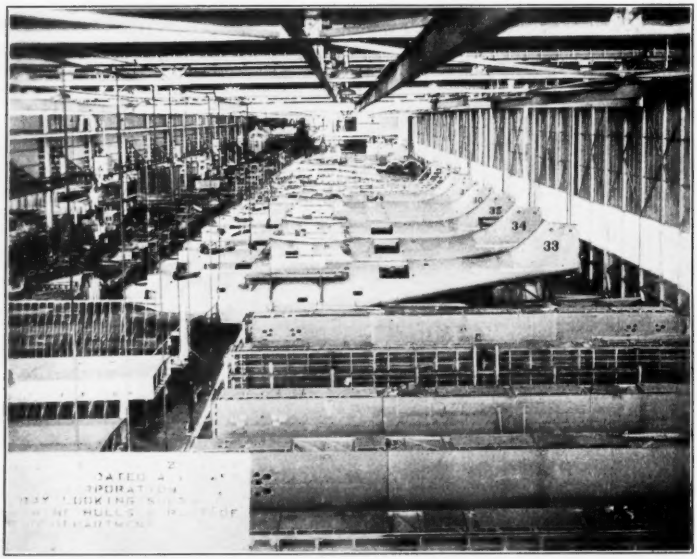


FIG. 76.
*Hull assembly line at Consolidated Works.*

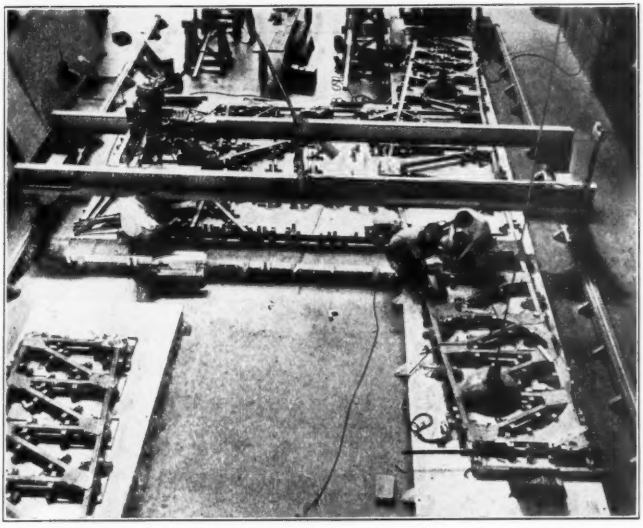

FIG. 77.
*Fabrication of "Clipper" centre section bulkhead at Boeing Works.*

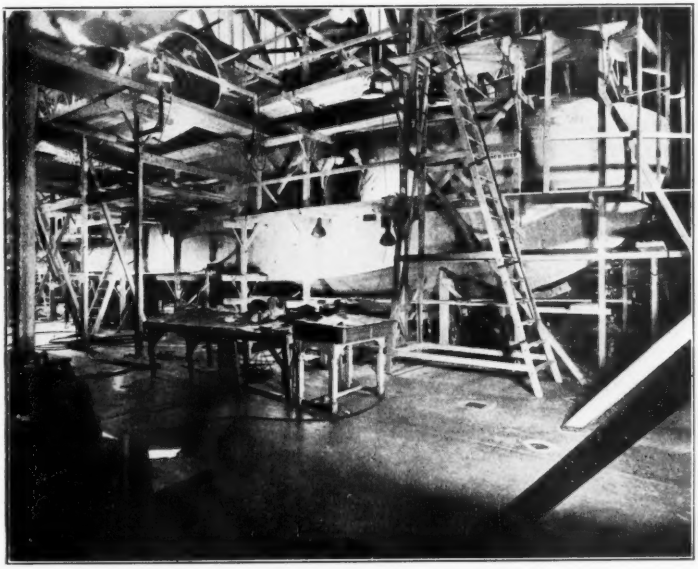

FIG. 78.
*View of the "Clipper" bow under construction at Boeing Works.*

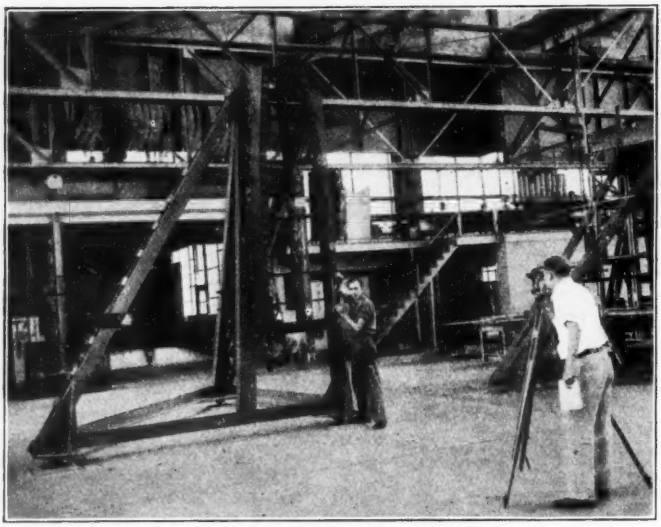

FIG. 79.
*Use of surveying transit for lining up large jigs at St. Louis Works of Curtiss-Wright.*

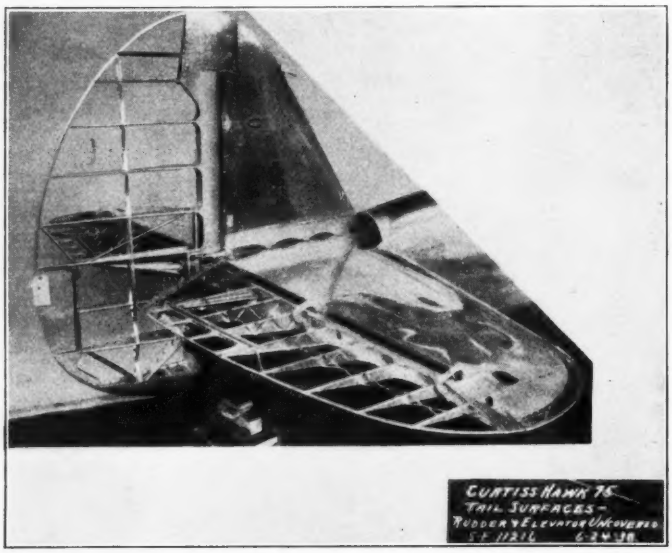


FIG. 80.
*Partially completed tail surfaces of the Curtiss "Hawk" 75 at Buffalo Works of Curtiss-Wright.*

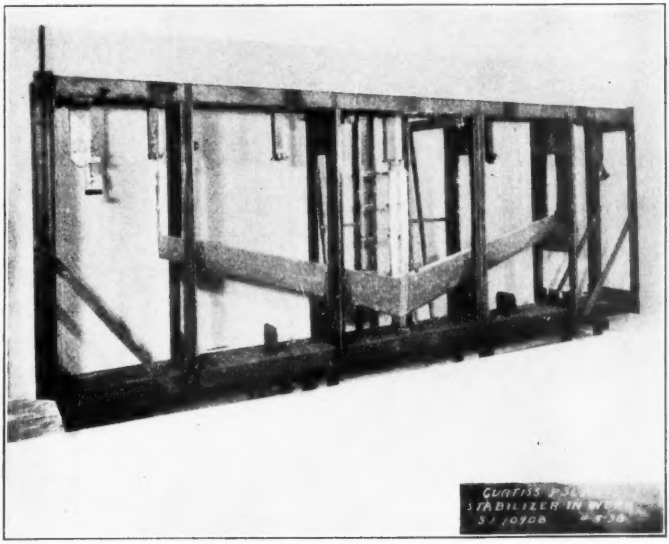

FIG. 81.

*Construction view of the Curtiss "Hawk" 75 stabiliser at Buffalo Works of Curtiss-Wright.*

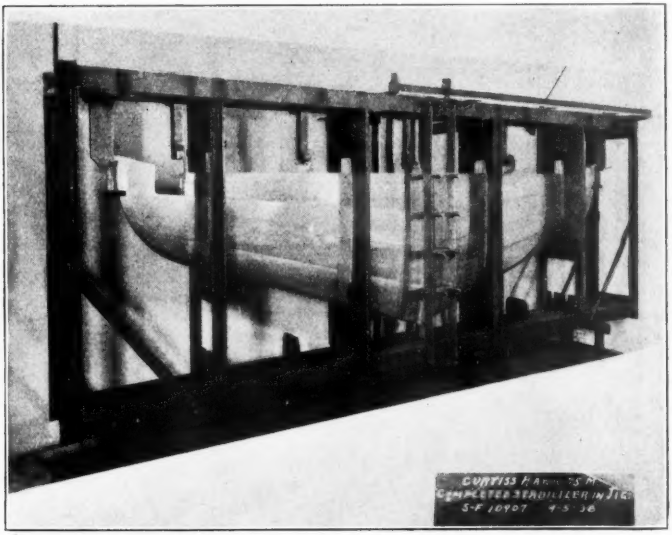

FIG. 82.

*Construction view of the Curtiss "Hawk" 75 stabiliser at Buffalo Works of Curtiss-Wright.*

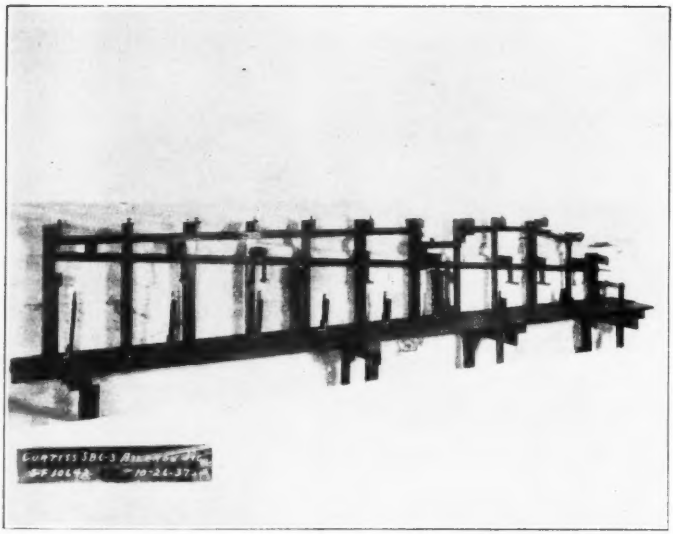

FIG. 83.
*Construction view of Navy Scout Plane aileron jig at Buffalo Works of Curtiss-Wright.*

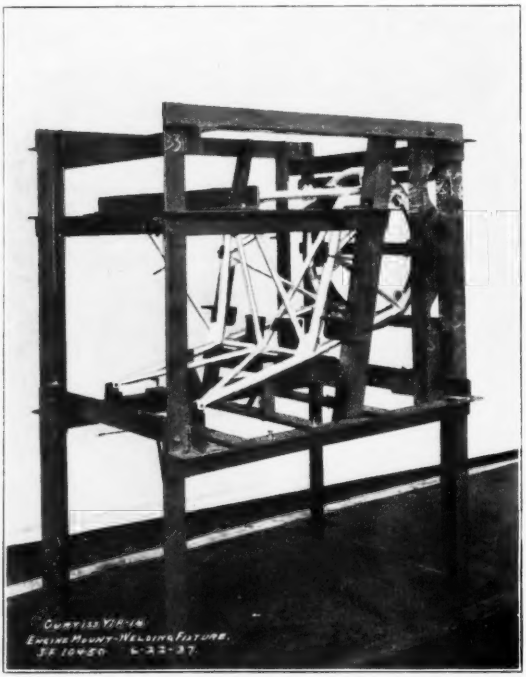


FIG. 84.
*Construction view of a welded tubular engine mount for a U.S. Air Corps attack plane at Buffalo Works of Curtiss-Wright.*

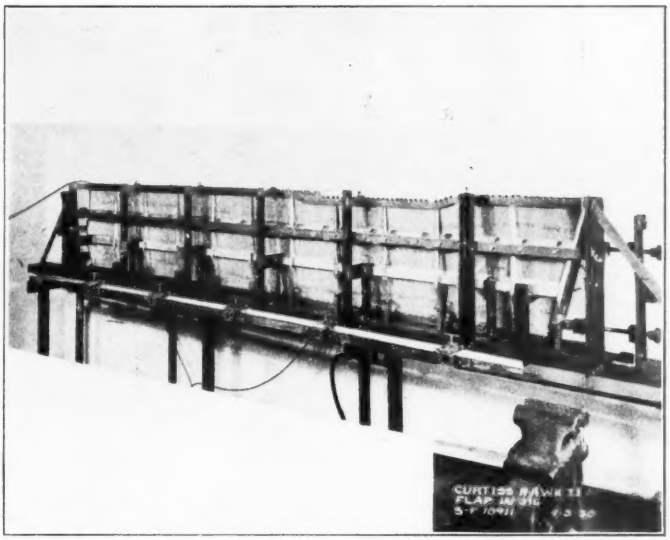

FIG. 85.
*Construction view of the assembly jig used for flap of Curtiss "Hawk" 75 at Buffalo Works of Curtiss-Wright.*

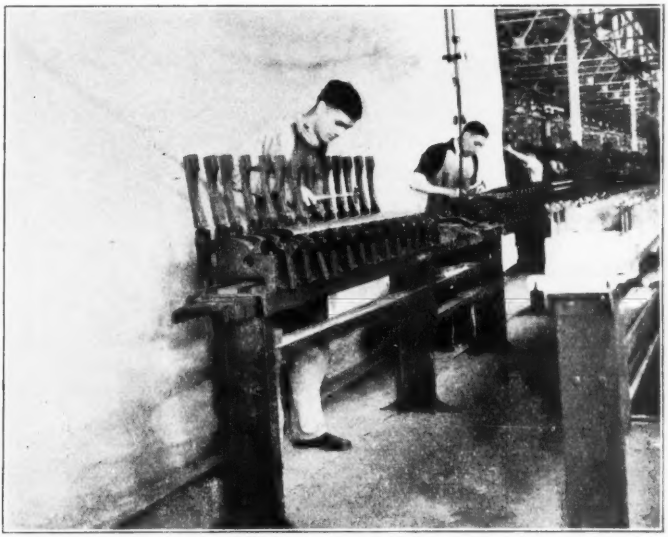

FIG. 86.
*Construction view of the assembly jig used for auxiliary aerofoil at Buffalo Works of Curtiss-Wright.*

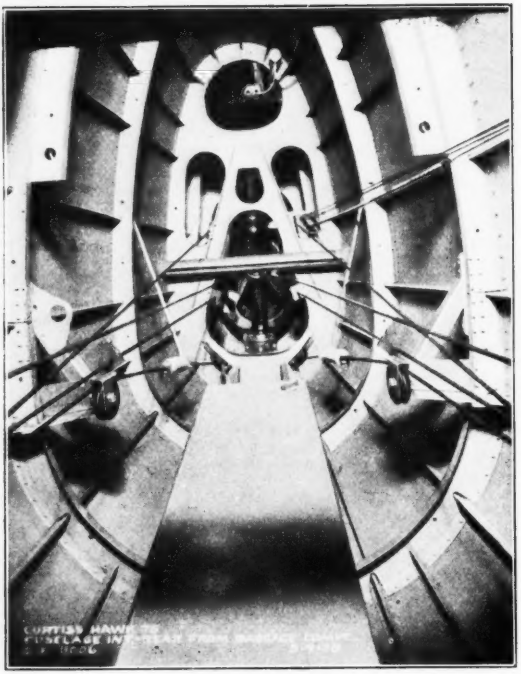

FIG. 87.
*Interior construction view of Curtiss "Hawk" 75 fuselage showing bulkhead and stringer design.*

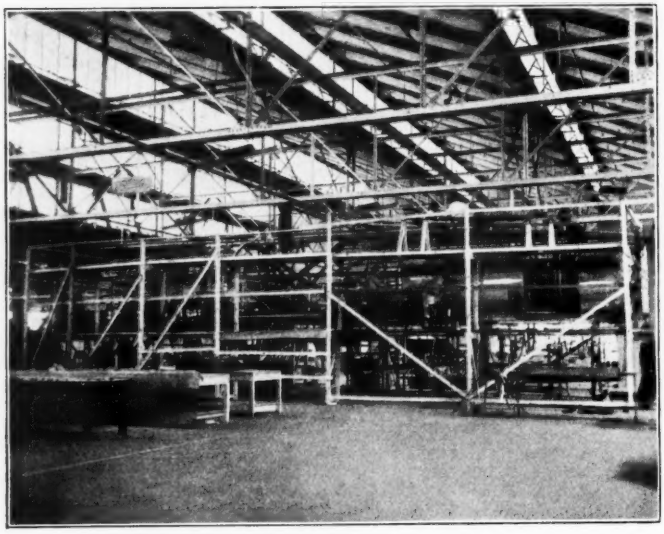

FIG. 88.
*Early construction view of the fuselage of the Curtiss-Wright 20 transport at their St. Louis Works.*

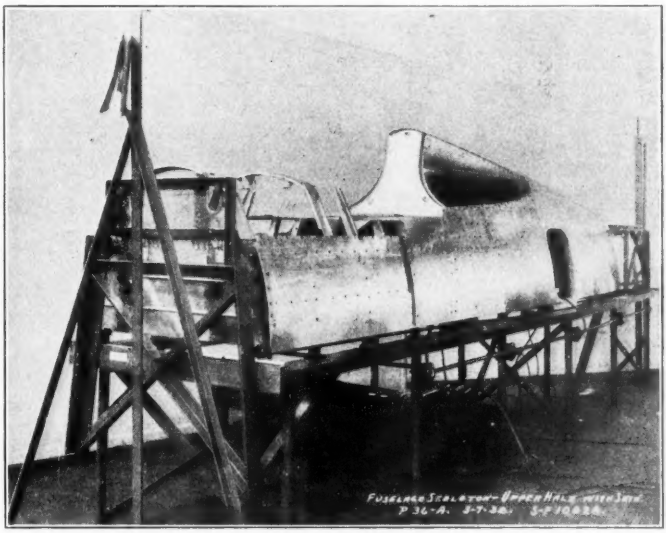

FIG. 89.

*Construction views of the Curtiss "Hawk" 75 fuselage, showing its assembly in two halves on two separate jigs, at Buffalo Works of Curtiss-Wright.*
*Top half.*

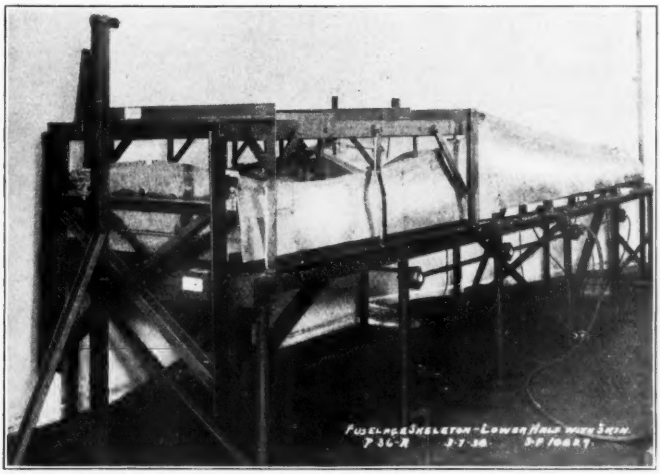

FIG. 90.

*Construction views of the Curtiss "Hawk" 75 fuselage, showing its assembly in two halves on two separate jigs, at Buffalo Works of Curtiss-Wright.*
*Bottom half.*

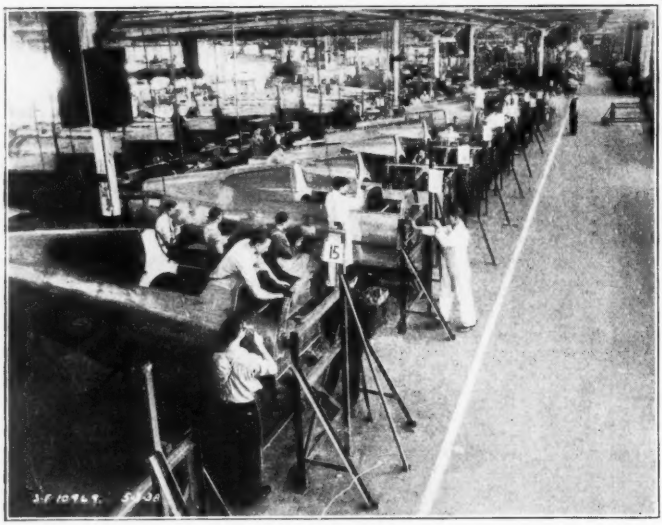

FIG. 91.
*"Hawk" 75 fuselage assembly line at Buffalo Works of Curtiss-Wright.*

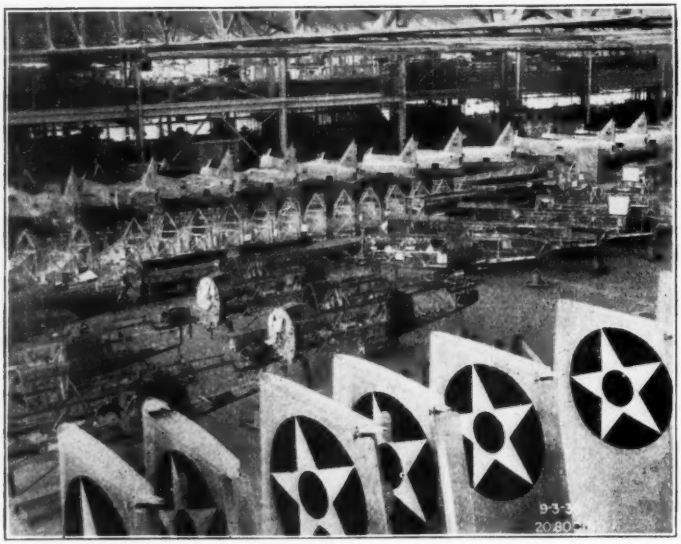

FIG. 92.
*View of the main assembly floor at the North American Aviation Works.*

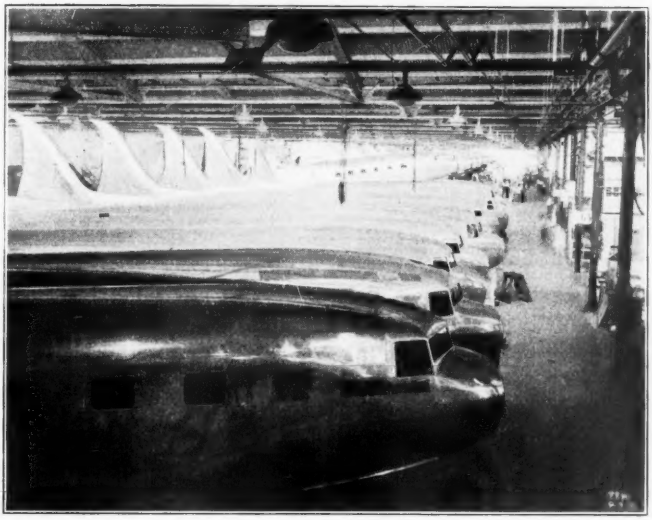

FIG. 93.
*An impressive view of the fuselage assembly line at the Douglas Works.*

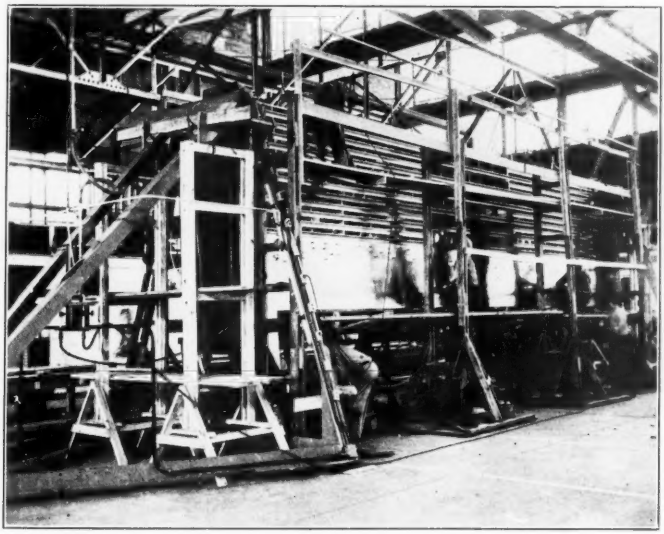

FIG. 94.
*Construction view of the wing for the Curtiss-Wright 20 Transport at their St. Louis Works.*

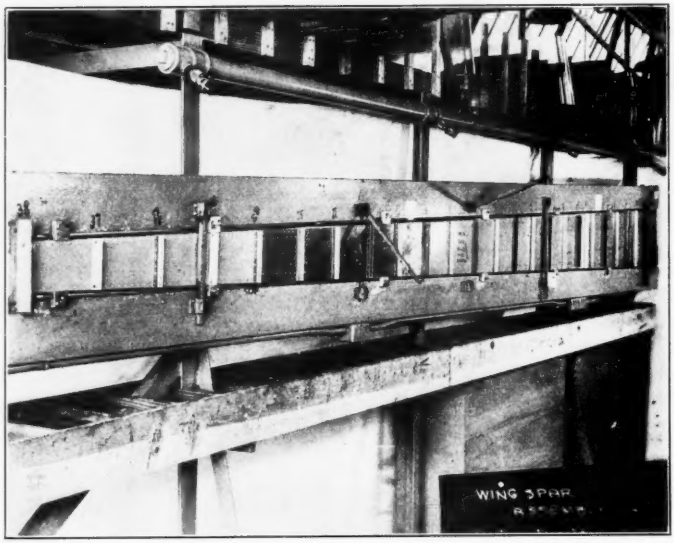


FIG. 95.
*Wing construction view taken at the North American Aviation Works, beam sub-assembly.*

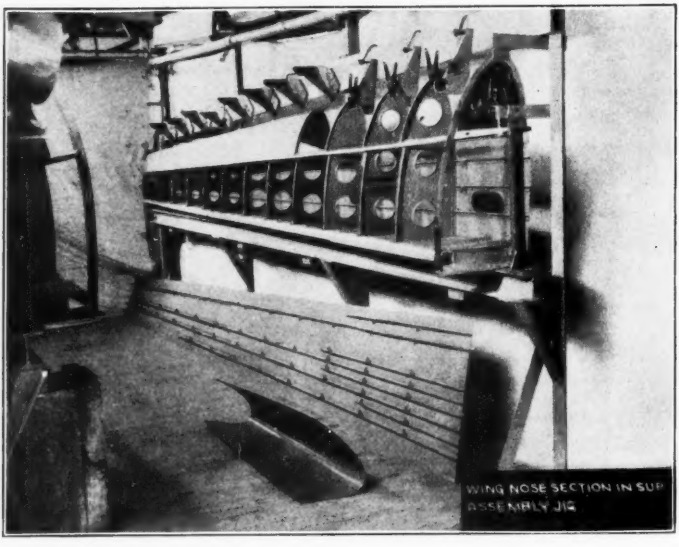


FIG. 96.
*Wing construction view taken at the North American Aviation Works, leading edge sub-assembly.*

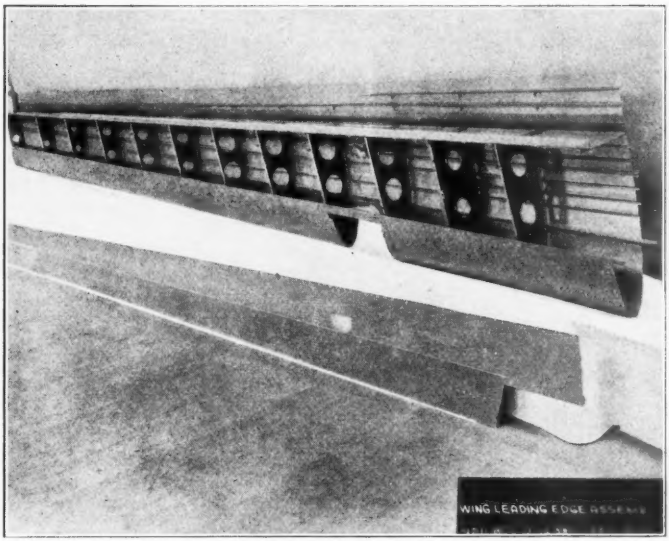


FIG. 97.
*Wing construction view taken at the North American Aviation Works, leading edge sub-assembly.*

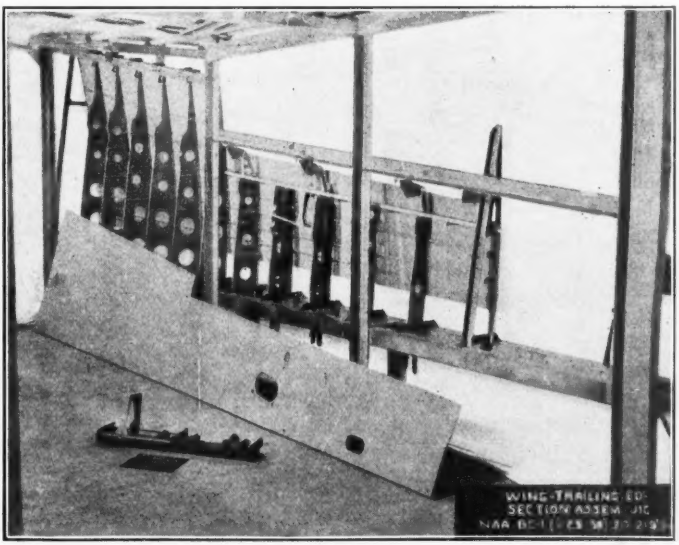


FIG. 98.
*Wing construction view taken at the North American Aviation Works after portion sub-assembly.*

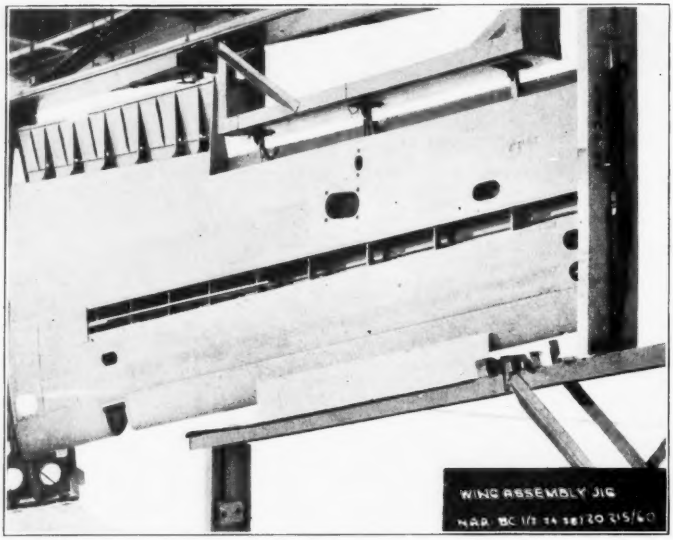


FIG. 99.
*Wing construction view taken at the North American Aviation Works, wing assembly.*

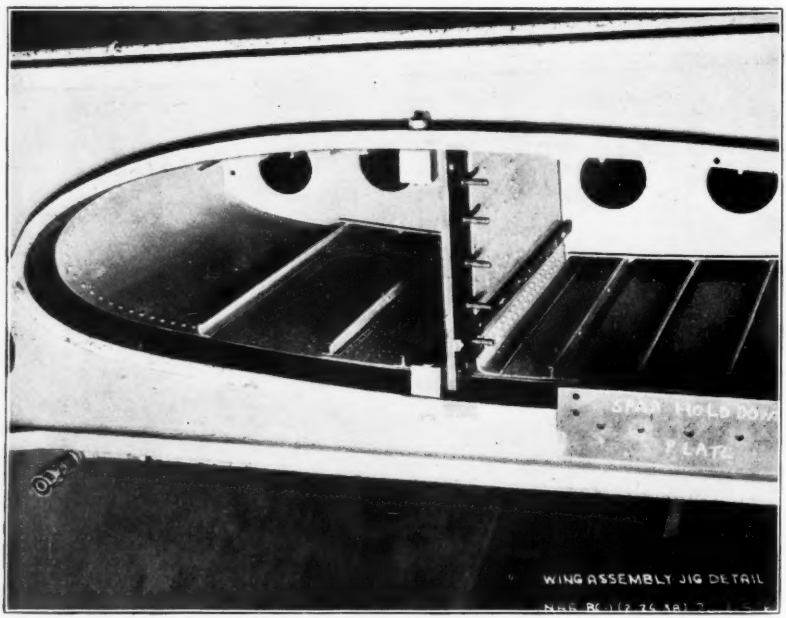


FIG. 100.
*Wing construction view taken at the North American Aviation Works, end view showing wing construction.*

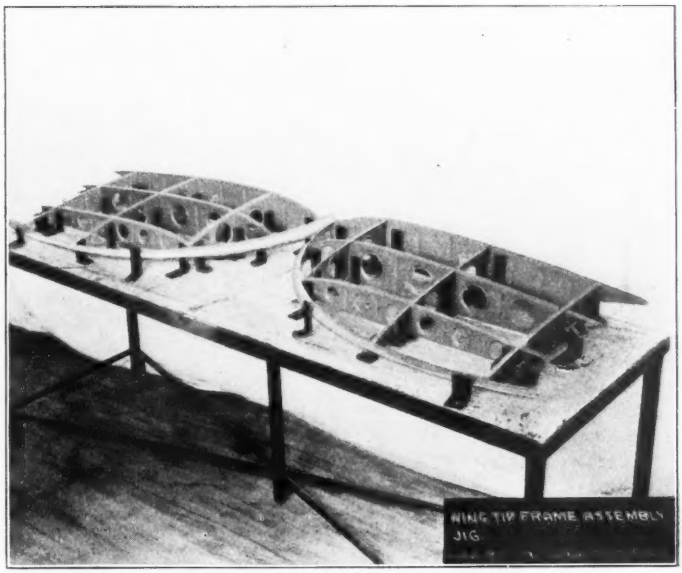


FIG. 101.
*Wing construction view taken at the North American Aviation Works, wing tip sub-assembly.*

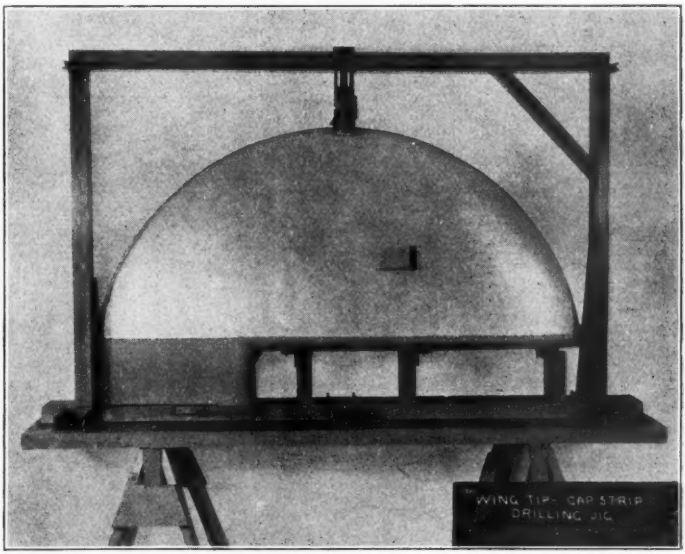


FIG. 102.
*Wing construction view taken at the North American Aviation Works, tip drilling jig.*

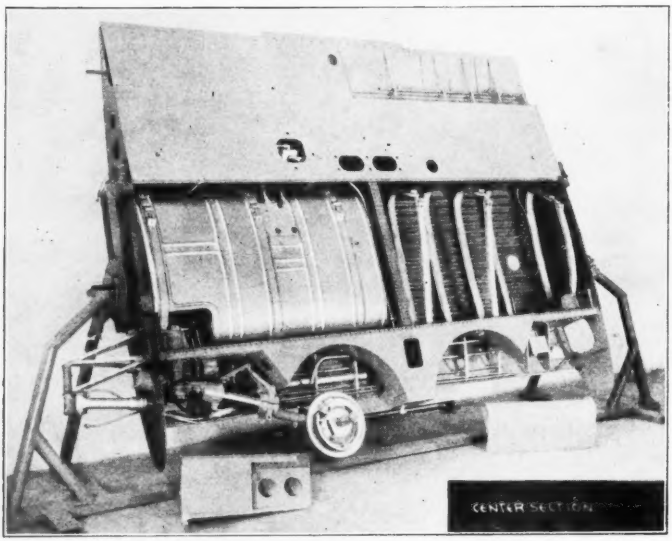


FIG. 103.
*Partially completed centre section of a North American Aviation model, showing details of fuel tank and landing gear installations.*

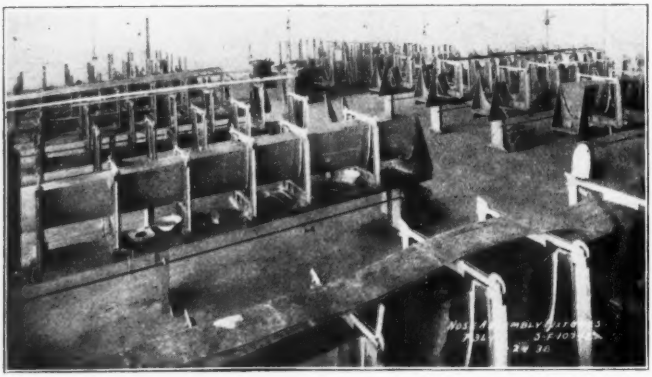

FIG. 104.
*Wing construction view of the Curtiss "Hawk" 75 at their Buffalo Works, leading edge jigs.*

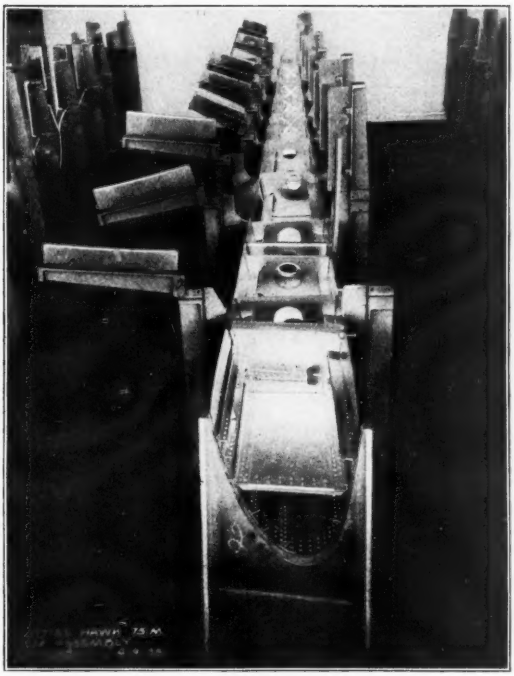

FIG. 105.
*Wing construction view of the Curtiss "Hawk" 75 at their Buffalo Works, detail of leading edge sub-assembly.*

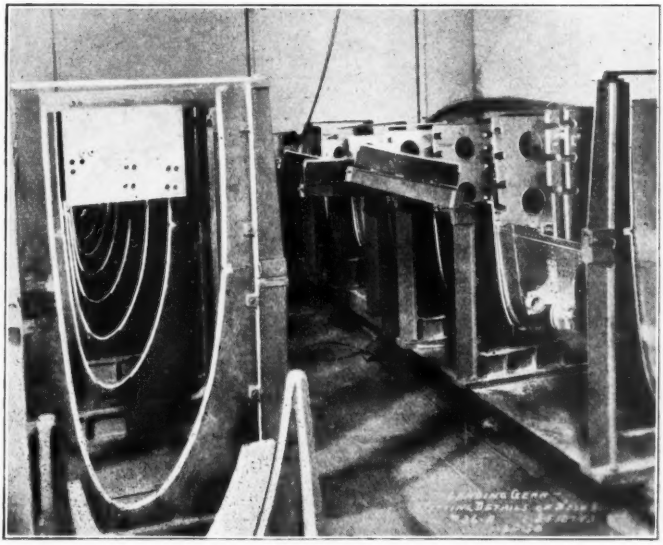

FIG. 106.
*Wing construction view of the Curtiss "Hawk" 75 at their Buffalo Works, showing second stage in sub-assembly.*

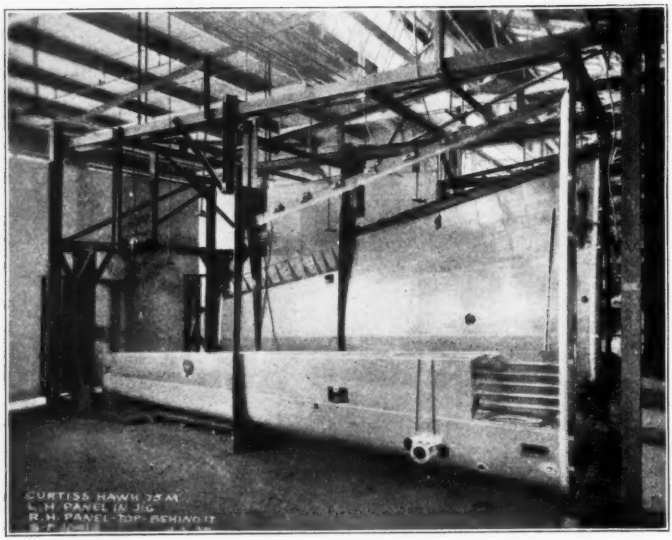


FIG. 107.
*Wing construction view of the Curtiss "Hawk" 75 at their Buffalo Works, starting wing assembly.*

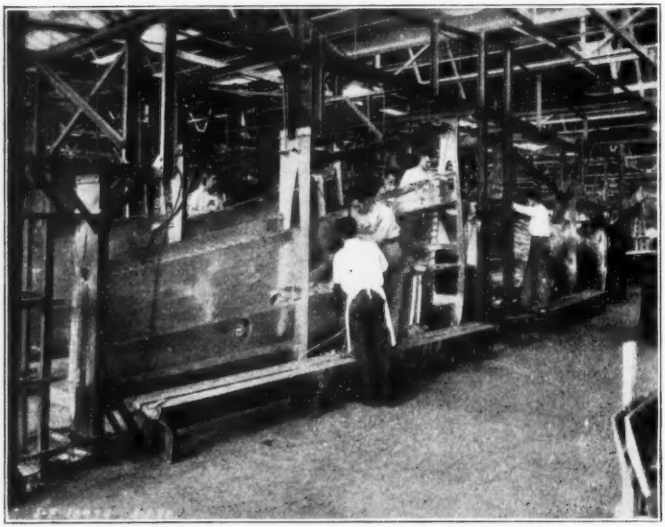

FIG. 108.
*Wing construction view of the Curtiss "Hawk" 75 at their Buffalo Works, finishing wing assembly.*

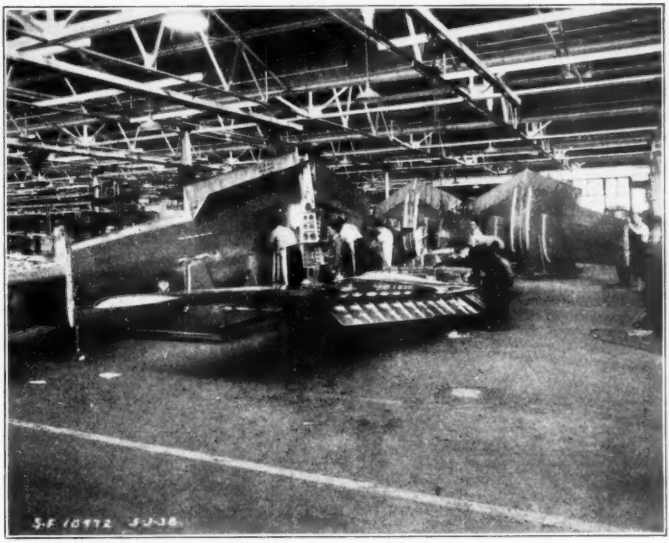

FIG. 109.
*Wing construction view of the Curtiss "Hawk" 75 at their Buffalo Works, completed wings.*

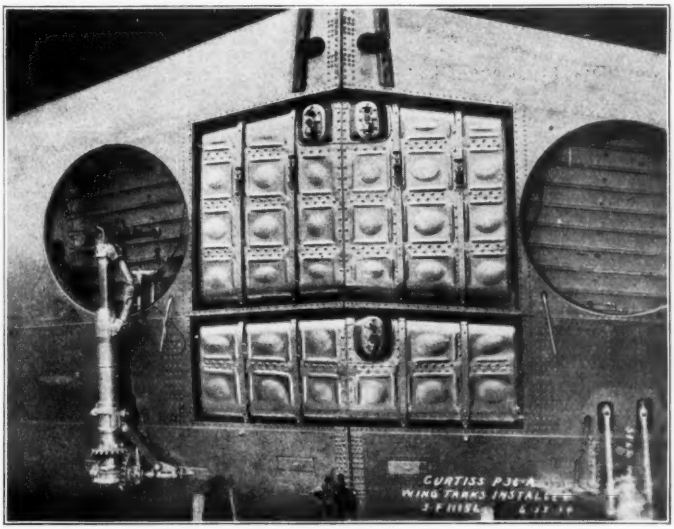


FIG. 110.
*Partially completed centre section of Curtiss "Hawk" 75, showing details of fuel tank and landing gear installations.*

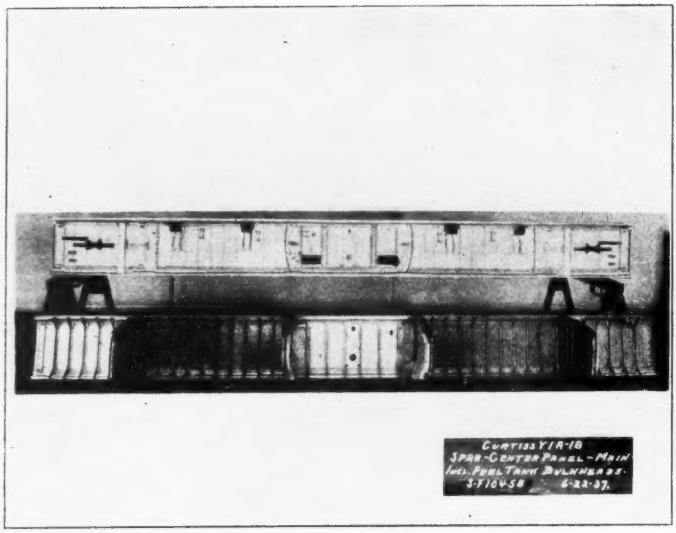


FIG. 111.

*Detailed construction view of metal mono-spar for Curtiss U.S. Air Corps attack model being fabricated at Buffalo Works of Curtiss-Wright.*

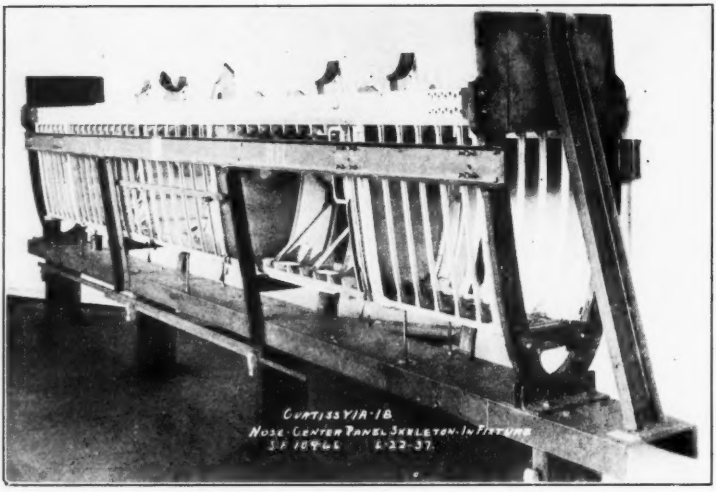


FIG. 112.

*Detailed construction view of mono-spar for wing of Curtiss U.S. Air Corps attack model being fabricated at Buffalo Works of Curtiss-Wright.*

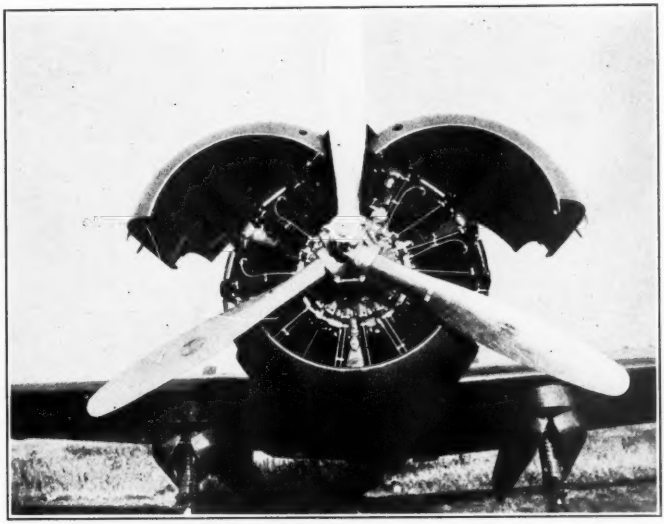

FIG. 113.
*View of the model 19-R of Curtiss-Wright St. Louis Works, clearly indicating the great accessibility to the engine installation by virture of the specially designed cowling.*

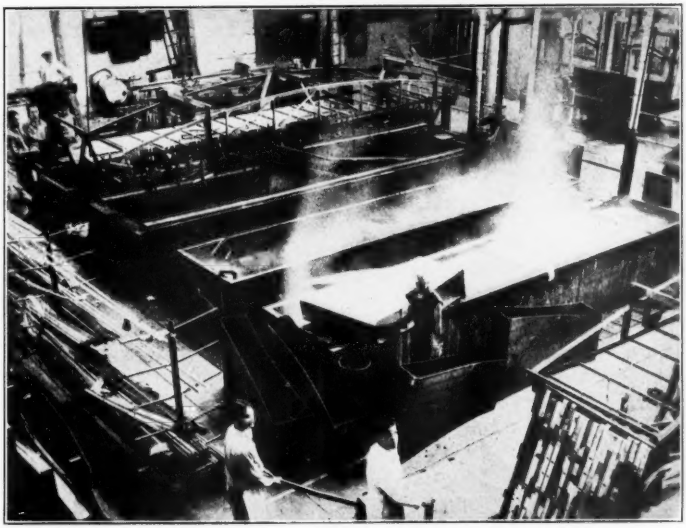

FIG. 114.
*Anodising tanks at the Consolidated Works.*

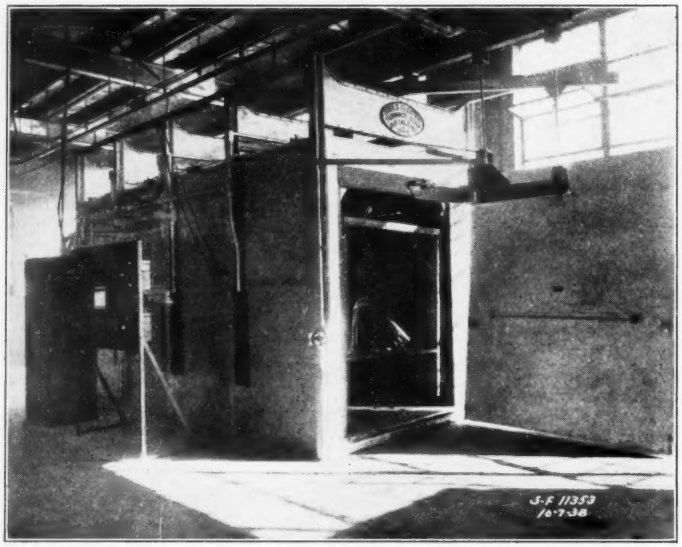


FIG. 115.
*Electric heat treat furnace at the Buffalo Works of Curtiss-Wright.*

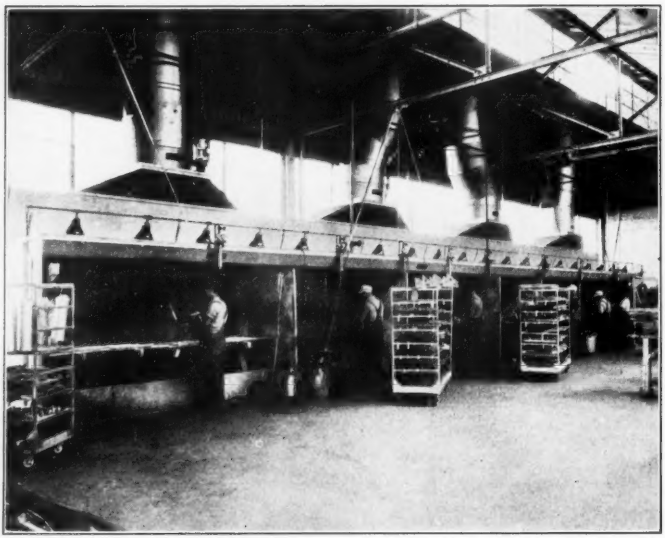

FIG. 116.
*Paint spray booths for parts at the Buffalo Works of Curtiss-Wright*

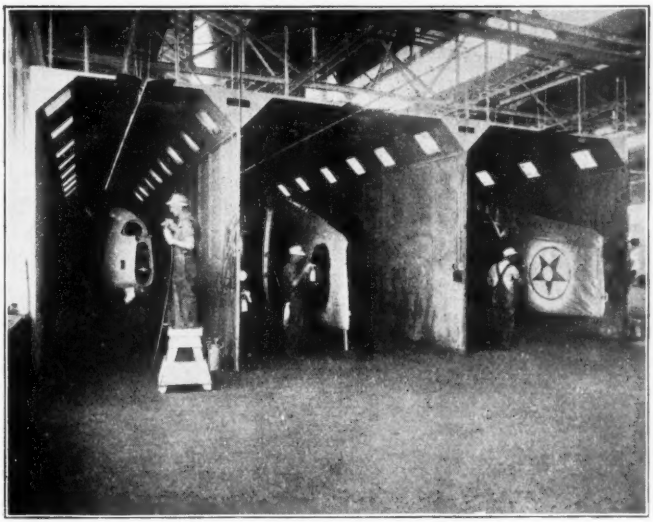

FIG. 117.
*Paint spray booths for major assemblies at the Buffalo Works of Curtiss-Wright.*

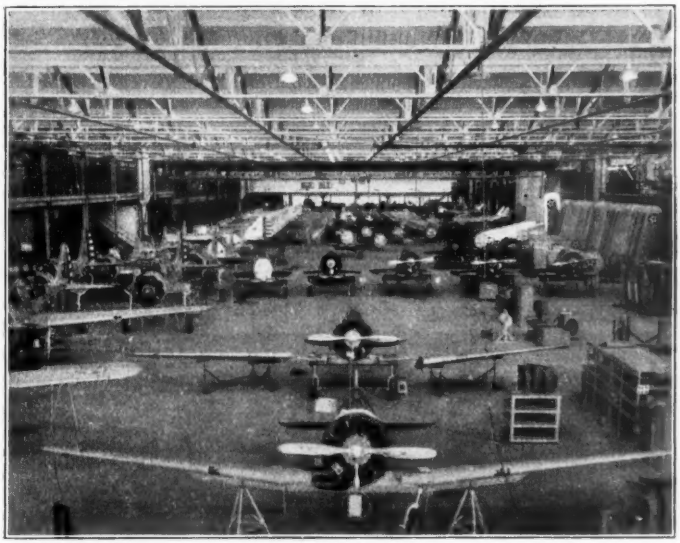

FIG. 118.
*General view of the final assembly floor of the North American Aviation Works*

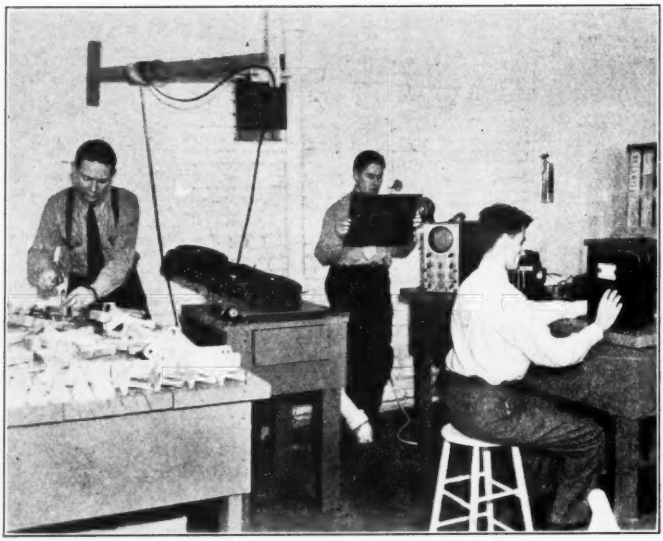

FIG. 119.
*Use of X-ray apparatus for inspection purposes at the Lockheed Works.*

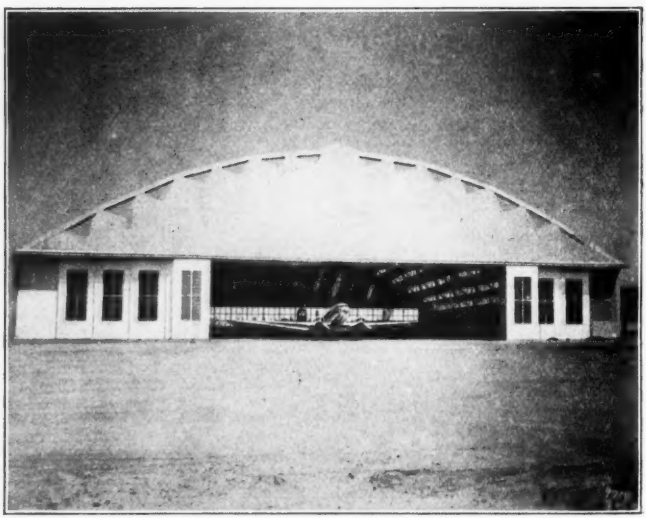

FIG. 120.
*General view on the ground of a Douglas DC-2 Transport.*

FIG. 121.
*Flight view of Curtiss P-36A U.S. Air Corps Pursuit Ship.*

FIG. 122.
*General water view of the Boeing "Clipper."*

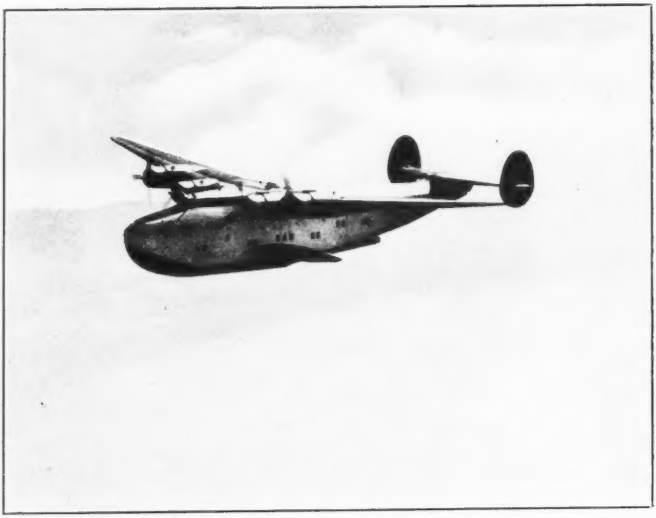

FIG. 123.
*General flight view of the Boeing "Clipper."*

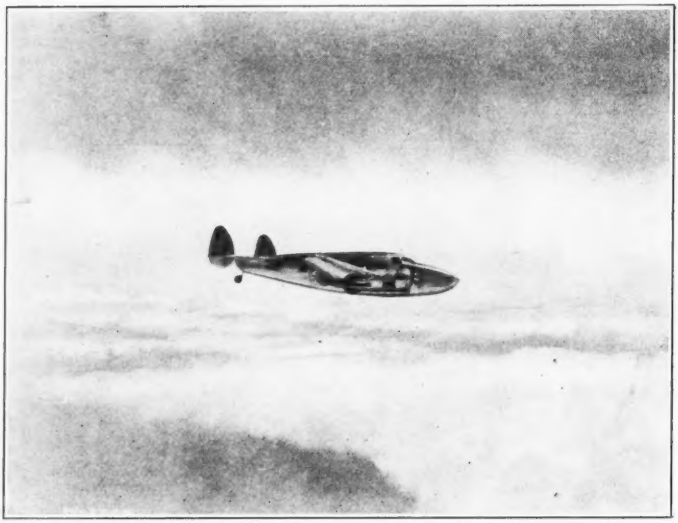

FIG. 124.
*Flight view of the Lockheed "14" Transport.*

FIG. 125.
*Flight view of the Curtiss-Wright 19-R military trainer, produced by their St. Louis Division.*

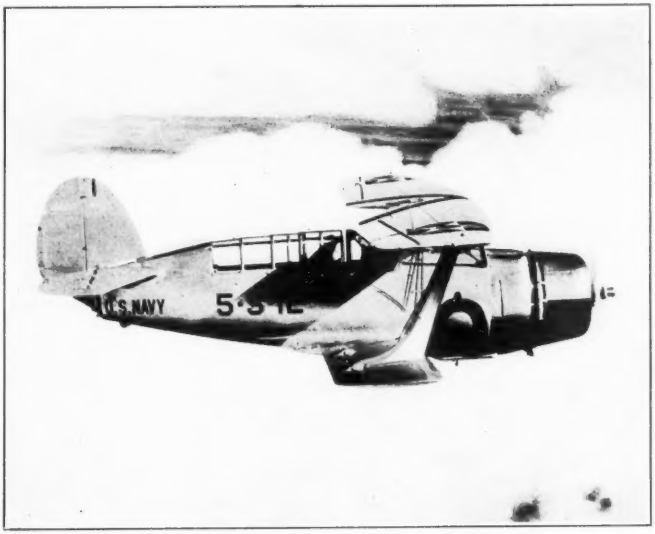


FIG. 126.
*Flight view of the Curtiss SBC-3 U.S. Navy Scout observation plane.*

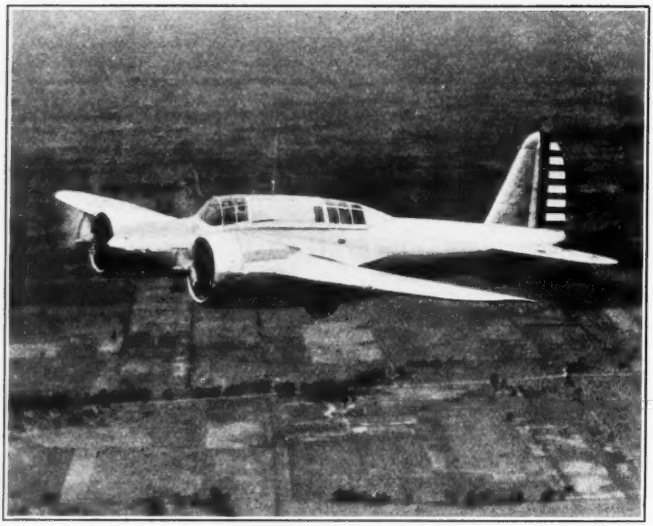

FIG. 127.
*Flight view of the Curtiss Y1A-18 U.S. Air Corps attack plane.*

(*Continued from page* 152.)

From a chart of a drawing office organisation it was pleasing to find that there was so large a percentage of draughtsmen devoted to weights. Perhaps that had been rather neglected in the past by some, but there was no doubt that there should be a very close check on that right from the beginning, especially when aircraft as at present went straight from the drawing board into full production.

It was not quite clear where Mr. Wright scheduled his jig and tool draughtsmen. Aircraft manufacturers in England employed a great number of jig and tool draughtsmen apart from those who might be employed outside on sub-contracts. He believed that the American aircraft manufacturers dealt with concerns which employed their own jig and tool draughtsmen more than we do in this country. He believed also that when American aircraft manufacturers wanted forgings or extrusions, they merely sent out a plain drawing and secured delivery in quantity within a fortnight, whereas manufacturers in England might have to wait three or four months, and uncertain at that, all tending to make production planning different in the two countries.

Asking for some amplification of the reference in the paper to tool and labour proportions, he was not sure how the figure of 50 per cent. was arrived at. The 40-50 per cent. was very much on the high side compared with British practice. Perhaps it included some of the special gear like the heavy presses.

It was of interest to note that Mr. Wright touched upon the very sore point of modifications. We in this country still were affected, although now the production people definitely had the last word.

Mr. J. D. North (*Fellow*): As one who had visited the United States on several occasions and had seen many of the things which Mr. Wright had described, he acknowledged the debt due to American engineers in respect of the development of new methods in the manufacture of aircraft of skin construction.

He was in complete agreement with all that Mr. Wright had said both as regards the work that had been done and that which needed to be done; particularly he emphasised the importance of design for production. It was essential that draughtsmen engaged on design should have real practical experience, and at the very commencement of the design of a new aeroplane they must be able to view every feature of the work in the light of the manufacturing conception. If there was not a manufacturing conception at the beginning of design, it was very difficult to improve production by subsequent modification.

Mr. Wright: Dealing with Major Barlow's reference to the chart of aeroplane quantity production cost curves, he said that the Government Department in America did use them. Up to the quantities for which he had data to back them, from 200 to 250, they represented very accurately the reduction of costs with increasing quantity. Of course, that reduction of costs was not automatic; there must be the proper quantities of tools and proper design of tools in order to ensure decreased costs with increased quantities as portrayed by the curves. Proper regard must also be paid to other factors which cheapened production, such as improvement in efficiency through motion study, etc. During the last 15 years he had kept records of anything that could have any bearing on that matter, and the figures were remarkably close to the curves on the chart. Incidentally, he said that in an earlier paper, which was published in the "Journal of the Institute of Aeronautical Sciences" (Feb., 1930), there was a very broad discussion, and he had made investigations in the automobile industry in order to find whether there was correlation there. He had investigated the position in a number of automobile plants of which he knew the production fairly well, and had arrived at the costs per lb. of those automobiles, and he had found that even there his curves, crude as they might be, fitted quite well.

Any aeronautical engineer would appreciate that weight control was the essence of the whole business. Dr. Hunsaker, in 1921, in his Wilbur Wright Lecture,

had dealt with weights and had said that an aeroplane was either a success or a failure when it first came off the scales. A proper weight control section was necessary in any engineering department.

Jig and tool design in America was usually dealt with in the production department or the planning department; in the Curtiss-Wright organisation the tool draughtsmen were entirely in planning. The planning of the work in the shop was so intimately tied up with the tools used in manufacture that tool drafting was best done in the planning department. On the other hand, the loft was in the charge of the engineer because it was in reality a glorified drawing board; nevertheless, it was used by the planning department in making patterns, which in a way were tools.

The period in which forgings were delivered was not quite so short as Major Barlow had suggested. On the average there was a period of from four to five weeks from the time the information was released so that the making of dies could be commenced, to the receipt of finished forgings.

The tool to labour proportions were the total tool costs (whether the tools were made at the aeroplane factory or were purchased outside) in relation to the production labour in the aircraft factory. If he were building a prototype machine he would expect to spend 8 per cent. as much on tools as on direct labour; if the number were 100, the expenditure on tools would be 20 per cent. as much; if there were 250, it would be 40 per cent. as much. In other words, in order to secure the advantage of the reduction of labour costs with increasing output as shown in the chart, the tools must be increased in somewhat these proportions. He could only vouch roughly for the percentages about 250 aeroplanes, at which point he arrived at the 40 per cent. figure. In one case more than that percentage was spent, and it was felt that in that case too much had been spent, but in another case a little less than that figure was spent and it proved under-tooled. As to whether or not the percentage would be 50 for 1,000 machines, perhaps the British manufacturers would be able to answer that question in another year or so.

Mr. H. J. POLLARD (*Fellow*): The paper was the most valuable that he could remember having been presented to the Society on the problems of production, and he urged that the Council should endeavour to get more papers of that type in the future.

With regard to the necessity for draughtsmen to acquire practical experience, it seemed that there were so many young fellows in the shops who were technically trained or were being trained, that there should be no difficulty in filling the design offices with men who had had factory experience.

It was surprising to learn from the paper that only three per cent. of the total floor area was occupied by the wood working department. That appeared to him to be a very small percentage, and he would have suggested 10 per cent. in a factory making machines which were supposed to be "all-metal."

In this country the steels used were mainly manganese carbon steels and not chromium-molybdenum. The manganese carbon steels were cheaper than the chromium-molybdenum steels, and they could very easily be welded.

He was convinced that nothing like enough use had been made of magnesium sheet in this country, some simplification of structure should result from its use.

With regard to works organisation, he had been very depressed to read in the paper that for an organisation of the type illustrated the total overhead expense to be applied to direct labour when determining cost would range from 60 to 75 per cent. However, before one could comment very much on that aspect it was necessary to read the paper carefully, for it contained a very great deal of valuable information. All concerned with the industry were very much indebted to Mr. Wright for the paper and it was to be hoped that before he returned to America he would visit again some of the factories in this country. Those concerned with the factories might not be able to teach him very much, but they would certainly try to do so.

Mr. WRIGHT: In reply to Mr. Pollard's reference to the size of the wood-working department, the wood-workers and pattern makers employed represented 3 per cent. of the total personnel; it was not stated that the floor area occupied by the wood-working department was 3 per cent. of the total floor area of the factory, but the percentage of floor space might be greater than that. The wood-workers did practically nothing else than make forms and patterns for the foundry and shop.

With regard to stainless steel, he had wished to leave the impression that he did not think it was the correct material to use for the stressed skin type of construction. But it would work out well in the beam type of construction, metal covered back to 30 per cent. of the chord, the beam taking most of the bending load itself. Then the leading edge portion of the wing would be sufficiently thick to take all the torsion satisfactorily and economically; then behind it the wing would be covered with the very lightest possible construction of ribs and fabric. Stainless steel was very poor for use in the stressed type of construction, because for paper thicknesses it was necessary to use a terrific amount of stiffening; it was not believed to be so good in that type of construction both from the standpoint of cost and strength/weight ratio.

Commenting on Mr. Pollard's remarks concerning the employment of automobile engineers in aircraft factories, one should not go too far in that direction. Two or three men who were well acquainted with automobile production methods could be very valuable in the aircraft factory by reason of the suggestions they could make concerning the application of methods of fabrication with which they were familiar. If, however, they came into an aircraft factory with the idea that they could become aeronautical engineers all of a sudden there would be plenty of trouble.

Mr. WESTBROOK: He asked whether the stretcher press was used in America, and what was the position of the Douglas patent for shearing plate using rubber on the hydraulic press; it was noticed it was being used extensively in U.S.A. We over here did not think the patent was valid.

Mr. WRIGHT: It was used by Douglas and some others, but he was not familiar with the patent situation.

Mr. WESTBROOK: With regard to labour costs, it was being found in this country, in view of the very large extensions that were being made in manufacturing plants, that costs were likely to go up, because the labour had to be trained and the usual rates had to be paid, although the men were inefficient. He wondered whether the experience was similar in America as manufacturing plants extended.

He asked if many extruded sections were used as no mention had been made of them. He believed that most of us in this country had been copying America for some time.

Mr. WRIGHT: He knew of no actual aircraft factory in America which used a stretcher press as used in Germany, but certain other industries to which the aircraft industry sub-contracted part of its work were using stretcher presses. However, they were used very little indeed. Mr. Henry Berliner, of the Engineering and Research Company, had been very much impressed by the stretcher press in Germany, and had developed it to an extent even beyond that to which it was developed in Germany. Strangely enough, he had not, it was believed, sold any of them in America, but had, it was understood, sold several to Russia. But Mr. Wright was not entirely sure that it was economical to perform by means of the stretcher press an operation which could be performed by means of the hammer or by the hydraulic press with rubber pads and dies, and he did not think the stretcher press would be used very much in America for some time to come. One advantage of it was that one could use a very cheap form, built of rough cut wood.

Discussing the problem of labour costs in relation to the expansion of manufacturing plants, it was inherent in the situation that as more and more tools

were developed a cheaper class of labour could be employed, because the use of the tools called for less and less skill; that was one of the reasons why the labour costs curve was in the downward direction. But he urged that both America and Great Britain must go in for real up-to-date apprentice systems such as were applied in Germany; then we should get further.

Mr. G. R. VOLKERT (*Fellow*): Referring to the table in the paper showing the numbers of men within each of the several branches of aeronautical engineering in an organisation, "assuming that the total number of men engaged on a project was 200," he pointed out that that number included six project engineers. His understanding was, that a "project" was a single design, and he wondered whether the figure of 200 represented the total number of people in the drawing offices, or the number engaged on one very large project. In any case, he asked what was the effectual distinction between the "project engineer" and the "designer."

He also asked whether American aircraft manufacturers were worried, as were the manufacturers in this country, by requirements such as that in order to prevent corrosion all painted joints must be assembled with the paint still in the wet condition. That requirement was a terrible nuisance and it extended the time occupied in assembling, but it had to be met.

Mr. WRIGHT: Usually one project engineer and his assistant were engaged on each particular design, and the six men listed in the table referred to by Mr. Volkert as "project engineers" would be sufficient for three designs; in other words, there was a total of between 60 and 70 persons engaged on one particular design.

Replying to the question concerning the distinction between the project engineer and the designer, he would like to have the qualifications of both incorporated in one man. Experience had shown, however, that very seldom did one man incorporate executive abilities and the qualifications of a designer; so that it was necessary to employ a project engineer and a designer on each particular job, simply because men were not usually able to perform the two diverse types of work. It was probable that a designer would not be a good administrator, and a project engineer would not be a good designer. He could think of only two or three men who were good designers as well as good executives; such a man would perform the functions of both, with the aid of perhaps two assistants instead of one.

With regard to the requirement that joints should be assembled in the wet condition, he asked whether that applied only to seaplanes and boats.

Mr. VOLKERT: It applied to all aircraft, and the purpose was to avoid corrosion.

Mr. WRIGHT: In the American factories "Alclad" was used for the most part, and that provided fairly good protection in itself. At any rate, there had been no trouble, so that he did not think wet assembly was necessary, certainly in landplanes. However, that was a matter for the Air Ministry to determine from service experience.

Rear-Admiral Sir MURRAY SUETER, Kt., C.B., M.P.: Congratulating Mr. Wright upon his very able paper and excellent illustrations, he said it was fitting that he should do so, because he had started the Curtiss Company on the first rung of the ladder of prosperity, having placed with that company millions of pounds worth of orders, when head of the Royal Naval Air Service, for seaplanes and land planes during the war for the training of our pilots; our own factories in Britain were thus released for the production of war machines, and Sir Murray asked Mr. Wright to convey to the company his grateful thanks for the assistance they gave us during the war.

A question which Sir Murray put to Mr. Wright was whether experiments had been conducted in America on laminated wood, *i.e.*, material consisting of thin layers of wood pressed together under heavy compression.

Another question was whether Mr. Wright would agree that aeroplane and seaplane designs were rather too complicated nowadays. When visiting various

aircraft works Sir Murray had been impressed by the thousands and thousands of rivets used in modern construction, and by the thousands of spare parts and drawings that were necessary. He suggested, therefore—even in the presence of Sir Charles Craven—that a panel of aeronautical engineers might be set up to consider the whole question of the simplification of aeroplane and seaplane design, for he was quite certain that the result would be to quicken and cheapen production.

Finally, he thanked Mr. Wright again for having given so much valuable information.

Mr. WRIGHT: He would be glad to convey to his company the message which Sir Murray had given him.

Replying to the question concerning laminated wood, Colonel Clark, of Clark "Y" aerofoil fame, was working on that type of material, developing a seven-ply structure with resin impregnation between laminations, and he believed that the laminations were pressed together under heat. Although he was not very familiar with it, he believed it was something like the construction of the Schwartz propeller.

Rear-Admiral Sir MURRAY SUETER: He supposed that the laminations were very fine.

Mr. WRIGHT: He agreed, and if one made up a structure comprising seven laminations, to a total thickness of $\frac{1}{8}$in. or $\frac{3}{16}$in., the laminations were very thin and permitted of very complete impregnation with resinous material. The material was claimed to be very advantageous from the standpoint of cost particularly, and also from the standpoint of weight and aerodynamic smoothness. However, the development was entirely in the research stage, and it would not come before the general public for a little while.

With regard to the complications of present-day designs, whilst appreciating that it was a commendable ideal to reduce complications, he could not hold out too much promise of such reduction. Some fuselages were quite simple and very good, but others seemed very complicated. He expected improvements in all parts of the aeroplane and the seaplane. But the installations were becoming so complicated, and the requirements of customers were such, whether in regard to civil or Government aircraft, that the structures were bound to be quite complicated. The aircraft industry was sometimes criticised in that respect by people in other industries who did not quite appreciate the nature of the installation problem. A man who walked through a factory, particularly where civil aircraft was built, and saw miles and miles of wiring and heating conduits, and hundreds of instruments, might ask why the quantities should not be cut down. But it could not be done in that way. The manufacturers were not installing anything that was unnecessary. The aircraft structure itself, as distinct from the installations, was not too bad at present, though rivets were costly and the manufacturers would like to reduce the number. He, personally, felt that the thing to do was to eliminate them and to substitute spot welding, which perhaps would be more amenable to production when it was finally developed. But until that time arrived, and certainly for the next two or three years, the aeroplane as a whole would remain quite complicated.

Mr. H. BURROUGHES (*Fellow*): It appeared that America and Great Britain had the same system of internal inspection in aircraft production, but that the system of Government aircraft inspection in America was different from ours. He asked for information as to the type of men employed as Government inspectors in America, and how far they went into the job. For example, he asked whether they started with the examination of the whole of the raw material and went right through the whole thing, or whether they carried out some sort of selective inspection.

Arising out of that, he asked to what extent the parts of American military aircraft were expected to be interchangeable. Was it a question of interchange-

ability of wings and flaps, ailerons, and so on, or did the American Government expect interchangeability of what we called the sub-components?

Mr. WRIGHT: Inspection was troublesome to the factory man, however one looked at it. But the American Navy made quite a complete inspection of raw material outside, and aircraft manufacturers had found it a great accommodation to be able to use that inspection and to have the raw materials inspected at the source, so that those materials would bear the Navy stamp when they arrived at the aircraft factories, and it was not necessary then to make chemical and physical tests after arrival.

The inspection by Government inspectors was more of a supervisory inspection. They required that the companies themselves should maintain very fine inspection departments, and he believed the Government inspection was a little more pointed towards inspecting the companies' inspection departments rather than inspecting material. He regarded that as correct; and he added that, as production increased and the works became larger, that system of supervisory inspection would have to maintain, because if the Government inspectors had to inspect and stamp every detailed part the delay would be too great and, with adequate company inspection, was unnecessary.

With regard to interchangeability, assuming Mr. Burroughes meant to ask whether one aileron, for instance, must fit on any machine of a type, there must be complete interchangeability in that respect.

Mr. BURROUGHES: He asked whether there must be interchangeability of the parts of the aileron as well?

Mr. WRIGHT: That was not necessarily so. The main parts which the Government would buy as spares must be interchangeable, but so far as the parts of the assemblies were concerned, it was up to the manufacturers themselves; lack of interchangeability might be disadvantageous to the manufacturers, from the point of view of cost.

Mr. GRIFFITH BREWER (*Hon. Fellow*): He recalled that when Professor Hunsaker had delivered his Wilbur Wright Lecture in 1921, H.R.H. the Duke of York (now H.M. King George VI) had presided and had made the very good suggestion, that there should be an exchange of information between aeronautical circles in America and Great Britain. Later, Professor Hunsaker had said that that had not been carried through. Now that Mr. Wright had presented his very interesting paper, however, there might be an exchange of information on aeronautics between American and British commercial circles. Mr. Wright's paper represented a very good start for the development of reciprocation of that kind.

Mr. A. H. HALL (*Fellow*): Discussing the very heavy presses used in the American aircraft factories, as illustrated in the paper, he suggested that the hourly charge must be very heavy. He asked for a little more information on that matter, particularly in regard to the load factor on a very large press, because that must affect the cost of working very considerably.

With regard to the forming of light alloys into the required shapes by means of a hammer, he would have thought that after the material had been subjected to that process its condition might be such that it was very prone to corrosion fatigue or other ailments. He asked whether that was the case where that method of production was applied. In that connection he recalled that formerly, in the manufacture of quick-firing cartridges in this country, if certain cartridge cases were sectioned and examined by means of the microscope it was possible to surmise the place of manufacture, because it was known which manufacturers used hammers and which of them applied hydraulic methods.

Mr. WRIGHT: He could not state off-hand the actual prices of the presses used in the American aircraft factories; but, of course, it was realised that the large presses must be used almost continuously in order to pay their overheads, and the arrangement of the feeding tables as he had indicated in the paper was made in order to keep the presses operating almost continuously. In the Curtiss-

Wright works at Buffalo the large press had three sets of tables, all on rollers manually operated. The Douglas works used electric control, and the North American Aviation works used hydraulic control. But the principle was the same in all cases; one or two men were employed to fill the table with pieces and matching patterns; it was then slid in, and the press came down. Then the next table was ready, and so on. He, personally, considered that the press in general was more desirable for forming than for cutting. The Douglas Company disagreed with that and carried out a lot of cutting with it. The Lockheed and North American companies preferred the movable arm router for cutting, and presumably both found their respective methods economical, for they had persisted during the last three or four years.

He was very sure that corrosion did not occur in light alloys as the result of subjecting them to the hammering operation. The material was not stretched; indeed, it was more likely to be compressed, in view of the quick impact of the hammer. If the hydraulic press were used with that kind of die there must be very carefully adjusted pads at the side to allow the material to slip in, whereas a hammer came down with a bang and the contour was formed without appreciably changing the thickness of the material. The important factor was the suddenness of the operation.

The CHAIRMAN: In proposing a hearty vote of thanks to Mr. Wright for his paper, he said the meeting had been privileged to hear a remarkably interesting and classic review of aircraft production methods in America, and he endorsed the comments of the speakers concerning the great value of the paper. The discussion had been somewhat disappointing, perhaps; but the paper contained so much information that it was felt that time was required to digest it, and he had no doubt that Mr. Wright would be prepared to reply to written contributions. The meeting wished to congratulate and to thank him.

The vote of thanks was carried with acclamation, and Mr. Wright briefly responded.

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Following the lecture the President, Mr. A. H. R. Fedden, M.B.E., D.Sc., M.I.A.E., M.S.A.E., F.R.Ae.S., gave a dinner in honour of Mr. T. P. Wright. The following accepted the President's invitation to be present:—

Mr. T. P. Wright, D.Sc., F.I.Ae.S., F.R.Ae.S.
Captain P. D. Acland.
Major T. M. Barlow, M.Sc.(Eng.), M.Inst.C.E., M.I.Mech.E., F.R.Ae.S.
Mr. Robert Blackburn, F.R.Ae.S.
Mr. O. Boden.
Mr. Griffith Brewer, Hon. F.R.Ae.S.
Major J. S. Buchanan, C.B.E., A.M.I.Mech.E., F.R.Ae.S.
Major G. P. Bulman, O.B.E., B.Sc., M.I.A.S., F.R.Ae.S.
Mr. H. Burroughes, F.R.Ae.S.
Mr. F. Butler.
Mr. S. Camm, F.R.Ae.S.
Dr. H. Roxbee Cox, D.I.C., F.R.Ae.S.
Sir Charles Craven.
Mr. Leo D'Erlanger.
Captain G. de Havilland, C.B.E., A.F.C., F.R.Ae.S.
Mr. W. C. Devereux, F.R.Ae.S.
Mr. E. Dixon.
Mr. A. Dunbar.
Mr. C. R. Fairey, M.B.E., F.R.Ae.S.
Sir Charles Bruce Gardner.
Mr. C. G. Grey.
Mr. A. H. Hall, C.B., C.B.E., M.Inst.C.E., M.I.M.E., F.R.Ae.S.
Professor G. T. R. Hill, M.C., M.Sc., M.I.Mech.E., F.R.Ae.S.

Mr. E. W. Hives.
Mr. J. L. Hodgson, Hon. F.R.Ae.S.
Mr. Paul Johnston, B.S., A.F.I.Ae.S.
Major D. H. Kennedy, O.B.E., F.R.Ae.S.
Mr. J. H. Kindleberger.
Major J. R. McCrindle.
Lieut.-Colonel W. Lockwood Marsh, O.B.E., M.A., Ll.B., M.S.A.E., A.F.I.Ae.S., F.R.Ae.S.
Major R. H. Mayo, O.B.E., M.A., F.R.Ae.S.
Mr. F. S. Mitman.
Lieut.-Colonel J. T. C. Moore-Brabazon, M.C., F.R.Ae.S., M.P.
Mr. J. D. North, F.R.Met.Soc., F.R.Ae.S., M.I.Ae.E.
Mr. F. Handley Page, C.B.E., F.R.Ae.S.
Dr. N. A. V. Piercy, M.Inst.C.E., M.I.Mech.E., F.R.Ae.S.
Mr. R. K. Pierson, M.B.E., B.Sc., F.R.Ae.S.
Professor A. J. Sutton Pippard, M.B.E., D.Sc., F.R.Ae.S.
Mr. C. M. Poulsen.
Captain J. Laurence Pritchard, Hon. F.R.Ae.S., A.F.I.Ae.S.
Mr. D. R. Pye, C.B., F.R.S., M.A., Sc.D., M.I.Mech.E., F.R.Ae.S.
Mr. H. Robinson.
Lord Sempill, A.F.C., F.R.Ae.S.
Mr. H. O. Short, F.R.Ae.S.
Mr. O. E. Simmonds, M.A., F.R.Ae.S., M.I.Ae.E., M.P.
Mr. Geoffrey Smith.
Group Captain J. Sowrey, A.F.C., F.R.Met.Soc., M.I.Ae.E.
Mr. G. Steel.
Sir Arthur Street, K.B.E., C.B., C.M.G., C.I.E., M.C.
Rear-Admiral Sir Murray Sueter, C.B., M.P.
Mr. Verdon Smith.
Air Vice-Marshal A. W. Tedder, C.B.
Mr. F. M. Thomas, A.F.R.Ae.S.
Sir Henry Tizard, C.B., A.F.C., F.R.S.
Mr. G. R. Volkert, F.R.Ae.S.
Mr. C. C. Walker, F.R.Ae.S., A.M.Inst.C.E.
Captain G. S. Wilkinson, M.I.Mech.E., M.I.A.E., M.S.A.E., F.R.Ae.S.
Mr. T. P. Wright, F.I.Ae.S., F.R.Ae.S.
Mr. A. P. Young.

# ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

*Issued by the*
*Directorates of Scientific Research and Technical Development, Air Ministry.*
*(Prepared by R.T.P.)*

No. 64. FEBRUARY, 1939.

*Engineering Precautions (Air Raid) Committee. Effect of Blast.* (Engineer, Vol. 147, No. 4332, 20/1/39, pp. 107-8.) (64/1 Great Britain.)

(1) Blast is a non-translational shock wave that is transmitted through the air to considerable distances from an exploding bomb. (2) Blast must be distinguished from the direct effect of the expanding gases, which involve pressures of much higher intensity and of different character, but effective only at short distances from the bomb. (3) A zone of expansion probably extends to a distance of about 25ft. for a charge which may be taken as representing a 500lb. bomb, and to a distance of about 65ft. for a charge of 1 ton of high explosive, representing a 3,000lb. bomb. (4) In the blast wave a phase of positive pressure is followed by a phase of negative pressure; the combined duration of the phases may range from about a hundredth of a second to a fifth of a second, according to the weight of the bomb. (5) The mean pressure in each phase of the blast wave is approximately in direct proportion to the reciprocal of the distance. (6) For targets of comparable static strength, those of higher frequency will in general be more easily ruptured by blast than those of lower frequency. (7) Of possible targets, windows may be subject to an equivalent static pressure of the same order as the momentary maximum intensity of blast, whilst walls and buildings may be subject to similar equivalent pressures if exposed to very heavy bombs.

Investigations on the following points bearing on the problem of blast are now in progress:—(*a*) The determination of the equivalent static pressure of the blast for different classes of targets. (*b*) Protective devices applicable to windows and glazing. (*c*) The magnitude of the pressure developed inside a shelter due to an external explosion.

*Materials in Relation to A.R.P.* (A. R. Astbury, Chem. and Ind., Vol. 58, No. 3, 21/1/39, pp. 41-5.) (64/2 Great Britain.)

(*a*) Reinforced concrete structures and steel-framed buildings, with fire-resisting roofs, floors, and walls, offer greater resistance to collapse and damage than other forms of structure. Buildings with load-bearing walls of brick or stone are liable to complete collapse. Buildings which are not fire resisting are liable to wholesale destruction. (*b*) Prolonged exposure to fire softens and disintegrates concrete whether used in reinforced concrete or as protection to steel framing. (*c*) The near effect of blast is to strip the concrete from the reinforcement which is left behind more or less intact. This effect may be also the result of overstressing of members due to falling debris. (*d*) Failure in reinforced concrete structures is likely to occur at the junctions between columns and beams, columns

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# ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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*(Prepared by R.T.P.)*

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*Engineering Precautions (Air Raid) Committee. Effect of Blast.* (Engineer, Vol. 147, No. 4332, 20/1/39, pp. 107-8.) (64/1 Great Britain.)

(1) Blast is a non-translational shock wave that is transmitted through the air to considerable distances from an exploding bomb. (2) Blast must be distinguished from the direct effect of the expanding gases, which involve pressures of much higher intensity and of different character, but effective only at short distances from the bomb. (3) A zone of expansion probably extends to a distance of about 25ft. for a charge which may be taken as representing a 500lb. bomb, and to a distance of about 65ft. for a charge of 1 ton of high explosive, representing a 3,000lb. bomb. (4) In the blast wave a phase of positive pressure is followed by a phase of negative pressure; the combined duration of the phases may range from about a hundredth of a second to a fifth of a second, according to the weight of the bomb. (5) The mean pressure in each phase of the blast wave is approximately in direct proportion to the reciprocal of the distance. (6) For targets of comparable static strength, those of higher frequency will in general be more easily ruptured by blast than those of lower frequency. (7) Of possible targets, windows may be subject to an equivalent static pressure of the same order as the momentary maximum intensity of blast, whilst walls and buildings may be subject to similar equivalent pressures if exposed to very heavy bombs.

Investigations on the following points bearing on the problem of blast are now in progress:—(*a*) The determination of the equivalent static pressure of the blast for different classes of targets. (*b*) Protective devices applicable to windows and glazing. (*c*) The magnitude of the pressure developed inside a shelter due to an external explosion.

*Materials in Relation to A.R.P.* (A. R. Astbury, Chem. and Ind., Vol. 58, No. 3, 21/1/39, pp. 41-5.) (64/2 Great Britain.)

(*a*) Reinforced concrete structures and steel-framed buildings, with fire-resisting roofs, floors, and walls, offer greater resistance to collapse and damage than other forms of structure. Buildings with load-bearing walls of brick or stone are liable to complete collapse. Buildings which are not fire resisting are liable to wholesale destruction. (*b*) Prolonged exposure to fire softens and disintegrates concrete whether used in reinforced concrete or as protection to steel framing. (*c*) The near effect of blast is to strip the concrete from the reinforcement which is left behind more or less intact. This effect may be also the result of overstressing of members due to falling debris. (*d*) Failure in reinforced concrete structures is likely to occur at the junctions between columns and beams, columns

and footings, floor slabs, and supporting beams. (*e*) Cornices and heavy ornamental stonework are a serious danger to personnel in the streets. (*f*) Floors are often pierced by steel beams falling endways. (*g*) The value of strutting ceilings over refuges has not been fully demonstrated owing to the lack of materials for providing such support. (*h*) When casement windows are open the glazing seems to suffer little from blast, but closed windows are damaged for about 150 to 200 yards from the explosion.

*Development and Experimental Testing of Self-Contained Mathematical Expressions for Quantities in Internal Ballistics, Especially Those for Maximum Gas Pressure and Muzzle Velocity.* (H. Langweiler, Z.G.S.S., Vol. 33, No. 10, 11, and 12, 1938, pp. 273-6, 305-9, 338-342.) (64/3 Germany.)

The author considers the problem of most favourable gun design for a given projectile (calibre and weight) and muzzle velocity.

Mathematical expressions for the following quantities are obtained:—

(*a*) Quantity of charge burnt when max. gas pressure is reached.
(*b*) Value of max. pressure.
(*c*) Gas pressure at end of combustion.
(*d*) Muzzle pressure.
(*e*) Distance moved by projectile when max. gas pressure is reached.
(*f*) Distance moved by projectile to the end of combustion.
(*g*) Velocity of projectile when max. gas pressure is reached.
(*h*) Velocity of projectile at end of combustion.
(*i*) Muzzle velocity of projectile.
(*k*) Time of combustion.
(*l*) Time for projectile to leave barrel.
(*m*) Efficiency.

The author shows how explosive constants obtained from pressure measurements on a certain gun can be applied to guns of different dimensions. The calibre range covered extends from the infantry rifle to about 6in.

*Approximate Formulæ for the Ballistics of Oscillating Bombs.* (H. Knobloch, Z.G.S.S., Vol. 33, No. 12, Dec., 1938, pp. 346-8.) (64/4 Germany.)

Formulæ and tables at present available for practical bomb ballistics are based on the assumption that the longitudinal axis of the bomb lies along the tangent to its path during fall, *i.e.*, that the $c$ value for the bomb remains practically constant. This assumption is only fulfilled when the bombs are suspended horizontally in the aeroplane. With vertically suspended bombs, whose longitudinal axes lie at right angles to the tangent to the path of fall at the moment of release, oscillations occur, which are damped out after a few seconds. During this short time the $c$ value varies from an initial high value to the smaller normal value corresponding to axial air flow.

Formulæ of the ballistics of oscillating bombs are deduced by dividing up this period of oscillation (not exceeding 5 secs.) into time intervals and considering the appropriate value of $c$ for each interval. Constants occurring in the fundamental equations obtained can be determined experimentally in the manner described previously for horizontally suspended bombs (Knobloch, Beitrage gur Ballistik v. Techn. Phys., Leipzig, 1938) and the problem solved graphically. Of interest is the change $\Delta X$ in horizontal range $X$ for a one degree change of incidence of the bomb for various values of the original incidence at release $\alpha$.

For an aircraft flying at 4,000 m. at a speed of 100 m./sec. the author gives the following values:—

| $\alpha$ (initial incidence of bomb). | $\Delta X$. |
|---|---|
| 90° (vertical release) ... ... ... | 46 m. |
| 60° (oblique release) ... ... ... | 70 m. |
| 0° (horizontal release) .. ... ... | 16 m. |

*The Rôle of the Independent (Shore-Based) Air Force in Naval Warfare.* (W. Gladisch, Marine Rundschau, Vol. 43, No. 12, Dec., 1938, pp. 887-897.) (64/5 Germany.)

According to the author, the independent air force by attacking all naval bases within reach will force the enemy fleet to seek shelter at a considerable distance. The resultant grouping of the fleet can be checked by long range reconnaissance flights and will be of the greatest strategical importance in the development of subsequent naval actions.

These duties are quite distinct from those of naval aircraft, which are nowadays recognised as an essential adjunct of every fleet, either in an offensive capacity (torpedo and bomb attack against surface vessels) or for short range reconnaissance.

Shore-based aircraft can also be used under certain circumstances to attack convoys or isolated merchant ships. Such duties, however, require very special training.

In conclusion the author urges the closest co-operation between the sea and air forces. The admirals and naval chiefs of staff especially should be fully conversant with general strategical and tactical air problems and not be satisfied with a slight acquaintance of the specialised problem of naval aircraft.

There is always a tendency to overrate the difficulties connected with new weapons.

What is wanted is a clear realisation of their possibilities. A surprise by new methods of attack always carries with it the element of success.

*On the Transition from Laminar to Turbulent Flow in the Boundary Layer of a Sphere.* (S. Tomotika and I. Imai, Aer. Res. Inst. Report, No. 167, August, 1938.) (64/6 Japan.)

The momentum integral equation for the boundary layer on the surface of a body of revolution is applied to the case of the boundary layer of a sphere placed in a uniform stream. The flow in the boundary layer is assumed to be laminar and also the quartic form is assumed for the velocity distribution in the layer. For the velocity distribution just outside the boundary layer, use is made of each of three actual distributions which have been obtained from distributions of normal pressure measured by Fage, at Reynolds numbers just within, near the middle of, and above, the critical range respectively, over which the drag coefficient of the sphere experiences a large fall.

The differential equation for determining the thickness of the laminar boundary layer is solved, in each case, by the method of graphical integration and thus various characteristic quantities for the layer are calculated.

The results indicate that the flow in the boundary layer is everywhere laminar up to the point of separation, in accordance with the result of Fage's observation.

When the Reynolds number of the stream lies near the middle of the critical range, the departure of the observed values of the intensity of skin friction from the calculated distribution of the intensity of laminar skin friction occurs at a point near the observed point of minimum normal pressure.

The deviations of the experimental points from the calculated distribution curve of the intensity of laminar skin friction become more conspicuous when the Reynolds number of the stream is above the critical range. It is then found that the transition from laminar to turbulent flow begins in front of the point of minimum pressure.

*On the Stability of Vortex Sheets.* (G. Petrov, Trans. C.A.H.I. (Moscow), No. 304, 1937.) (64/7 U.S.S.R.)

The paper discusses the stability of vortex sheets both infinitely thin and of a finite thickness in a perfect uniform fluid.

The bulk of the work is confined to the determination of the distance between isolated vortices formed during the disintegration of unstable vortex sheets.

The results obtained by Rayleigh on the stability of rectilinear sheets (the two-dimensional problem) are supplemented by a detailed analysis of the case of two parallel vortex sheets. It is shown that in this case unsymmetrical oscillations are dominating (*i.e.*, the process of development of unsymmetrical oscillations goes faster than that of symmetrical ones), which contributes to the fact that behind a bluff body an unsymmetrical vortex row is formed.

A study of propagation of small oscillations in a circular jet of a uniform incompressible fluid bound by an infinitely thin vortex sheet was accomplished. The analysis has shown the instability of such a flow for any disturbances.

The stability of " zonal " oscillations of a circular jet bound by a sheet of finite thickness is investigated.

In conclusion, several considerations are given concerning the possibility of applying the results of investigation to the determination of the structure of the wake.

*Turbulent Boundary Layer of an Aerofoil. Part II. On the Resistance Law.* (K. Fediaevsky, Trans. C.A.H.I. (Moscow), No. 316, 1937.) (64/8 U.S.S.R.)

The present investigation represents a continuation of the work described in Report No. 282 of the Joukovsky Central Institute of Aerohydrodynamics.

A new form of the power law of resistance is developed allowing the expression of the numerical coefficient in the resistance law for any exponent in terms of the critical Reynolds number of the laminar sublayer.

The polynomial interpolation of the square root of the value of the frictional stresses in a turbulent boundary layer leads to much simpler laws for the velocity distribution as compared with those given in the first part of this work. Assuming the Prandtl mixing path to be proportional to the distance from the wall, formulæ for the velocity distribution are obtained which in a particular case (without a pressure gradient and inertia forces) assume the Prandtl-Nikuradse form.

The use of this law of velocity distribution leads to a very simple law of friction resistance which represents the generalisation of the Kármán logarithmic law of resistance for the case of a two-dimensional boundary layer with a positive pressure gradient.

The new law also explains the results of Fage and Faulkner (Symmetrical Joukovsky profile) and of Doensch and Nikuradse (flat diffusors) in a more satisfactory manner than the logarithmic resistance law.

*Turbulent Friction in the Boundary Layer of a Flat Plate in a Two-Dimensional Flow of Compressible Gas at High Speeds.* (F. Frankl and V. Voishel, Trans. C.A.H.I. (Moscow), No. 321, 1937.) (64/9 U.S.S.R.)

The present article is confined to the investigation of the compressibility effect and heating of a flate plate placed in a two-dimensional flow of compressible gas on the turbulent friction coefficient in a boundary layer of an aerofoil and a wing radiator. The analysis is based on the Prandtl-Kármán theory of a turbulent boundary layer and the Stodola-Crocco theorem of a linear dependence between the total energy of the flow and its velocity.*† Formulæ are obtained for the velocity distribution and the friction law in a turbulent boundary layer taking into account the compressibility effect and the heat transfer.

It is found that with increase of the compressibility and adiabatic temperature corresponding to fully retarded flow, the friction coefficient $c_f$ decreases.

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* L. Crocco. " Sulla trasmissione del calore da una lamina piana a un fluido scorrente ad alta velocita." L'Aerotecnica.

† A. Stodola. " Zur Theorie des Wärmeüberganges von Flüssigkeiten oder Gasen an feste Wände." Schweiz. Bauzeitung, Bd. 88, No. 18, 1926.

*The Consideration of the Viscosity Effect in the Kármán Turbulence Theory.* (G. Gurjienko, Trans. C.A.H.I. (Moscow), No. 322, 1937.) (64/10 U.S.S.R.)

The purpose of the present work was to integrate the equations of a turbulent flow in a pipe according to the Kármán theory, taking into account the viscous friction effect.

The results indicate that the consideration of the viscous friction effect has but a slight effect on the velocity distribution even at low Reynolds numbers.

Thus the consideration of the viscous friction does not eliminate the principal defect of the classical theory of turbulence developed by Kármán, *i.e.*, the 25-30 per cent. discrepancy in the values of the so-called "universal constant of turbulence" for the resistance law and velocity distribution.

In our previous work on the Mattioli Turbulence Theory (G. Gurjienko, "Viscosity Effect on the Turbulent Flow in a Rectilinear Cylindrical Pipe with Smooth Walls," Trans. of Aerohydrodyn. Inst., No. 303, Moscow, 1936) in which the viscous friction was also considered, it was shown that the Mattioli theory is free from the above mentioned defect, *i.e.*, the value of the universal constant of turbulence in this theory is the same both for the resistance law and the velocity distribution law.

The superiority of the Mattioli theory over the Kármán theory is thus not due to the consideration of the viscous friction effect, but to the fact that the Mattioli theory is apparently based on a more perfect model of the turbulent exchange.

*Effect of Profile Form on Frictional Resistance. Investigation of the Turbulent Boundary Layer in the Region of Breakaway.* (L. E. Kalikman, Trans. C.A.H.I. (Moscow), No. 333, 1937, 79 pp.) (64/11 U.S.S.R.)

A method is given for calculating friction drag and for determining the position of breakaway of the turbulent boundary layer from a wing profile. The theoretical distribution of intensity of friction over the surface of the wing, obtained by calculating the turbulent boundary layer by this method, is in good agreement with the experimental distribution.

The relationship between friction drag and the shape of a wing profile is investigated by carrying out the calculations for two series of profiles of different relative thicknesses. It is shown that:—

(*a*) At high Reynolds numbers the friction drag of wing profiles (of ordinary relative thicknesses) depends relatively little on the shape of the profile.

(*b*) Of all the geometrical parameters of a symmetrical profile, only the relative thickness has any considerable influence.

Formulæ are given for determining the coefficient of friction drag of a normal, smooth, symmetrical profile at high Reynolds numbers.

The method proposed by F. G. Glass for converting profile drag coefficients to higher Reynolds numbers is analysed from the point of view of the results obtained.

The point of breakaway of the turbulent boundary layer, determined from the condition that the friction stress becomes zero, can be found by extrapolation to any required degree of accuracy.

In conclusion, a full theoretical investigation is made of the turbulent boundary layer in the region of breakaway.

*An Analytical Method for Solving the Problem of Flow Around a Curved Arc with Breakaway of the Jet.* (Y. E. Sekerj-Zenkovich, Trans. Cents. Aero-Hydrodyn. Inst., Moscow, No. 354, 1938, 52 pp.) (64/12 U.S.S.R.)

This paper deals with the problem of the structure of a plane-parallel flow of ideal non-viscous fluid around a given curved arc, when the jet breaks away according to the well-known system of Helmholtz-Kirchhoff. The purpose of

the investigation is to obtain an analytical method for solving the problem of oblique impact for the general case of an arc of any type.

Firstly, the fundamental equation of the problem is solved analytically and the first approximate solution is calculated. The method is then applied to an arc of given shape, and approximate formulæ are deduced for determining the length of arc and its drag.

The formulæ obtained are applied to investigation of direct impact on particular types of arcs—arc of a circle, parabolic arc, arc of a cycloid.

*Some Applications of Conformal Representation to Hydrodynamics.* (Lavrentie, V., Proc. Joukowsky Academy of Military Aeronautics, 1935, No. 13, pp. 18-27.) (64/13 U.S.S.R.)

New methods involving the theory of conformal representation based on Koebe's theorem, are applied to the solution of certain hydrodynamic problems.

The author shows that by means of certain supplementary conditions, a wing whose contour is a circular arc can give the maximum lift.

A number of mathematical considerations relating to the principle of variation in conformal representation are analysed.

*Mathematical Problems in the Dynamics of Gases.* (F. Frankl, Proc. Joukovsky Academy of Military Aeronautics, 1935, No. 13, pp. 28-32.) (64/14 U.S.S.R.)

This paper deals with certain important mathematical problems connected with integration of the fundamental differential equation; and involves partial differential coefficients of the hyperbolic type for velocities greater than the velocity of sound, and partial differential coefficients of the elliptical type for velocities less than that of sound. The results obtained by the author and by other workers in elaborating these methods are analysed.

*Approximate Integration of the Equation for the Boundary Layer by the Methods Employed in the Theory of Heat Transfer.* (Leybenson, Proc. Joukovsky Academy of Military Aeronautics, 1935, No. 13, pp. 38-52.) (64/15 U.S.S.R.)

The author studies methods for approximate integration of the equation of the boundary layer, based on analogy with the problem of heat transfer.

The results are applied to the solution of the problem of breakaway of small streams of air from an arbitrary body situated in a current. The problem is studied for the cases of a plane surface, a circular or elliptical cylinder and a surface of revolution.

The position of the point of breakaway is determined theoretically for the elliptical cylinder and the surface of revolution.

*Flight Analysis of a Sounding Rocket with Special Reference to Propulsion by Successive Impulses.* (H. S. Tsien and F. J. Malina, J. Aer. Sci., Vol. 6, No. 2, Dec., 1938, pp. 50-8.) (64/16 U.S.A.)

In Part I of this paper an exact solution of the problem of determining the height reached by a body in vertical flight in vacuo propelled by successive impulses is presented. On the basis of this analysis it is concluded that a rocket propelled by successive impulses—the impulses being obtained, for example, from rapidly burning powder—can theoretically reach much greater heights than is possible by sounding balloons and, therefore, further experimental research is justified. In Part II the effect of the variation of the acceleration of gravity with height above sea level on the flight performance of a sounding rocket is analysed. For a 1,000-mile sounding rocket the decrease in gravitational pull

accounts for a 25 per cent. increase in the maximum height reached over that calculated on the basis of a constant gravitational acceleration. In Part III the fundamental performance equation for flight of a sounding rocket in air is expressed in terms of dimensionless parameters and factors and their physical significance is discussed. Finally, in Part IV the theory of the preceding sections is applied to a specific case of a sounding rocket propelled by successive impulses which are supplied by a reloading type of powder rocket motor.

*The Wave Resistance of a Ship's Propeller and Interaction with Wake and Waves Produced by the Ship.* (J. E. Dickmann, Ing.-Arch., Vol. 9, No. 6, Dec., 1938, pp. 452-486.) (64/17 Germany.)

The velocity potential and the equivalent sink distribution for the inflow of an ideal propeller are calculated with the help of the fundamental hydrodynamic equations. The interaction between ship and propeller is then studied in detail, special consideration being given to the following aspects of the problem:—

(1) Increase of ship's resistance on account of the reduced pressure field in front of the propeller.

(2) Loss of energy due to the propeller producing surface waves.

(3) Interaction with the waves produced by the ship.

The following conclusions are reached:—

(1) In the case of normal cargo boats, the increase in the ship's resistance above that corresponding to towing may amount to 20 per cent.

(2) The energy loss due to surface waves generated by the propeller is generally small.

(3) The interaction of these propeller waves with the waves due to the ship proper may, however, produce very important results.

Whenever possible the propeller should be situated below a wave crest.

*The Blade Design of Centrifugal Impellers.* (A. Betz and I. Flugge-Lotz, Ing.-Arch., Vol. 9, No. 6, Dec., 1938, pp. 486-501.) (64/18 Germany.)

The author shows how to calculate the shape of the blade for a given distribution of the circulation along the radius both for the case of constant and decreasing blade width. The results show that a decrease in the blade width mainly affects the mean radial flow through the impeller. The new method proposed by the author fills the gap between the two well known limiting cases: Infinite number of blades (solved by the Eulerian method) and widely spaced blades (solved by the method of conformal representation).

So far only the optimum theoretical working condition has been investigated (no shock loss at entry).

In a subsequent paper the author will demonstrate how the wing theory can be applied to estimate the losses occurring when the flow departs from this condition.

*On a Limiting Case of the Dimensional Unsteady Flow Round a Wing.* (V. Borbely, Z.A.M.M., Vol. 18, No. 6, Dec., 1938, pp. 319-342.) (64/19 Germany.)

The case of two-dimensional flow round an oscillating wing has already been solved. The author considers first the case of a finite supporting line with an elliptical vortex distribution. The results are next extended to cover the case of a finite oscillating wing of relatively small chord and possessing elliptical vortex distribution. Approximate expressions for the flow in the neighbourhood of the wing and for the angle of attack are obtained.

*On the Theory of Vortex Motion.* (A. Kneschke, Z.A.M.M., Vol. 18, No. 6, Dec., 1938, pp. 343-376.) (64/20 Germany.)

The author considers the motion of isolated vortices in any simply connected two-dimensional region. A relation is obtained between the kinetic energy and the " orbit function " of Kirchhoff, and a conformal transformation function for the energy is given.

The equation of motion of the vortex can also be deduced directly by applying the method of variation to the energy function of the vortex system.

*On the Measurement of Longitudinal and Lateral Velocity Variations in Turbulent Flow.* (H. Reichardt, Z.A.M.M., Vol. 18, No. 6, Dec., 1938, pp. 358-361. Göttingen Mathematical Congress.) (64/21 Germany.)

The author is specially concerned with non-isotropic turbulence, in which both lateral and longitudinal velocity variations occur.

The velocity measurements are usually carried out with hot wire instruments and the author describes a three-wire unit, the parallel wires being placed at the corners of an equilateral triangle, one corner facing the mean flow direction. The distance between the wires is very small (of the order of 0.1 mm.) the wires themselves being 0.01 mm. diameter. The three-wire instrument utilises the velocity and temperature gradients in the wake of the leading wire and is especially suited for low mean air speeds (below 100 cm./sec.).

Practical results obtained in a small wind tunnel under these conditions are described.

*Frequency Analysis of Turbulent Velocity Variations.* (H. Motzfeld, Z.A.M.M., Vol. 18, No. 6, Dec., 1938, pp. 362-365. Göttingen Mathematical Congress.) (64/22 Germany.)

It is usual to record the velocity variations during turbulent flow by means of hot wire anemometers. By means of a suitable amplifying circuit, the final voltage at any instant is proportional to the velocity variation. Previous investigators have carried out a frequency analysis by applying the resultant voltage to an electrodynamometer preceded by a filter which only allows known frequencies to pass. In this way the turbulence spectrum is obtained by a step by step method.

The author has devised an alternative method in which the resultant amplified voltage is applied to a number (10) of tuned mechanical resonators (torsion pendulums). The spectrum is deduced from the response of these resonators. The results obtained are in good agreement with those given by the filter method.

*The Calculation of Turbulent Separation of Flow.* (F. Schultz-Grunow, Z.A.M.M., Vol. 18, No. 6, Dec., 1938, pp. 367. Göttingen Mathematical Congress.) (64/23 Germany.)

The motion in the two-dimensional boundary at a flat plate is of the form

$$u\partial u/\partial x + v\partial u/\partial y = U\delta U/\partial x + (1/\rho)(\partial\tau/\partial y)$$

where $u$ and $v$ are the velocities and $x$ and $y$ the co-ordinates respectively parallel and perpendicular to the well. $U$ = velocity potential at outer edge of layer and $\tau$ = shear stress.

The author has analysed the experimental result of Gruschwitz on boundary layer flow and concludes that for

$$y/\delta \cong 0.15, \quad v\partial u/\partial y \text{ is approximately equal to } (1/\rho)(\partial\tau/\partial y).$$

In other words, the equation of motion for a strip of this nature is given by

$$u\partial u/\partial x = U\partial U/\partial x$$

and at separation

$$U_2^2 = U_1^2 - u_1^2.$$

*Wind Tunnel Measurements on Flat and Slightly Cambered Circular Plates.* (M. Hansen, Z.A.M.M., Vol. 18, No. 6, Dec., 1938, pp. 368-370. Göttingen Mathematical Congress.) (64/24 Germany.)

The aerodynamics of the circular plate were investigated theoretically by Kinner some time ago (Ing.-Arch., Vol. 8, Part I, 1937). The present paper deals with experimental measurements on the same subject, the plates being 40 cm. in diameter.

Speaking generally, agreement between theory and experiments is only satisfactory in the region of small lift coefficients.

The reasons for the discrepancies are discussed.

*Laws of Turbulent Flow in Open Channels.* (G. H. Keulegan, Bur. Stan. J. Res., Vol. 21, No. 6, Dec., 1938, pp. 707-41.) (64/25 U.S.A.)

The theoretical investigations of Prandtl and Kármán, and the experimental work of Nikuradse, have led to rational formulas for velocity distribution and hydraulic resistance for turbulent flow in circular pipes. With certain assumptions regarding the effects of secondary currents and of the free surface, and with the adoption of the hydraulic radius as the characteristic, similar rational formulas are deduced for open channels. The validity and the applications of these formulas are illustrated by a study of Bazin's experiment. In this study, the equivalent sand roughness of the channels used by Bazin are determined. The criterion for determining the conditions under which a channel with wooden plank surfaces is to be considered hydrodynamically wavy or hydrodynamically rough is also evaluated. The rational formulas with constants determined from Bazin's experiments are expressed in the form of power laws. It is shown that Manning's empirical formula is a good approximation to the rational formula for rough channels when the relative roughness is large.

*Cavitation Characteristics of Centrifugal Pumps by Similarity Considerations.* (G. F. Wislicenus, R. M. Watson and I. J. Karassik, Trans. A.S.M.E., Vol. 61, No. 1 (Sect. 1), January, 1939, pp. 17-24.) (64/26 U.S.A.)

Similarity considerations of hydraulic pumps and turbines can be obtained by comparing the known hydraulic performance of a given machine with the performance of other machines having geometrically similar waterways. The paper describes the application of this theory to the cavitation performance of centrifugal pumps and related machinery, and also introduces a characteristic parameter which, concerning cavitation performance, has properties similar to the specific speed with respect to other performance characteristics of such machines.

*Lateral Stability of Aeroplanes at Unsymmetrical Propeller Thrust.* (G. Scherbakov and F. Mamonov, C.A.H.I. Report No. 318, Moscow, 1937.) (64/27 U.S.S.R.)

After discussing several existing formulæ for the calculation of lateral stability, the author develops his own system of equations and obtains approximate solutions for the particular case of unsymmetrical thrust.

The theoretical data obtained in this manner are compared with the results of flight experiments. Flight methods and apparatus used are described and some foreign flight tests on stability briefly reviewed.

It appears that under condition of unsymmetrical propeller thrust (*e.g.*, only one of the two lateral engines working), the optimum attitude of the machine from the point of view of control is a bank together with a sideslip towards the working engine.

The optimum attitude for high speed flight will be discussed in a subsequent paper.

*Effect of the Shape of a Wing on the Load Distribution Along the Span and on the Longitudinal Stability.*. (A. B. Risberg, Trans. C.A.H.I., Moscow, No. 335, 1937, 80 pp.) (64/28 U.S.S.R.)

The results of this research were intended to provide some of the aerodynamic fundamentals for new strength specifications. The paper comprises a theoretical investigation of how the two most important design factors—load distribution and moment of longitudinal stability—depend on the main wing parameters. The investigation was based on a variation of Lotz's method. The modified method is employed to solve a few problems relating to trapezoidal wings, *i.e.*, determination of the main circulation round a plane wing and the additional circulations due to dihedral, deflection of ailerons and twist.

Calculations and graphs are given for the distribution of aerodynamic load on trapeze wings both with and without a rectangular centre section; these enable the effects of the various wing parameters to be studied.

A simple method is given for calculating the circulation for a wing of any shape, either plane or with any degree of dihedral, by means of numerical integration. Formulæ are deduced for determining the longitudinal stability of a wing of any shape from the curves for distribution of the relative loads.

Graphs are given to show the effects of spar, taper, dihedral angle, dimensions of the centre section and arrow formation of the wing, on the moment of longitudinal stability.

*The Negative Thrust and Torque of Several Full-Scale Propellers and Their Application to Various Flight Problems.* (E. P. Hartmann and D. Biermann, N.A.C.A. Report No. 641, 1938.) (64/29 U.S.A.)

Negative thrust and torque data for 2-, 3- and 4-blade metal propellers having Clark Y and R.A.F. 6 aerofoil sections were obtained from tests in the N.A.C.A. 20-foot tunnel. The propellers were mounted in front of a radial engine nacelle and the blade angle settings covered in the tests ranged from 15° to 90°. One propeller was also tested at blade angle settings of 0°, 5° and 10°.

A considerable portion of the report deals with the various applications of the negative thrust and torque to flight problems. A controllable propeller is shown to have a number of interesting, and perhaps valuable, uses within the negative thrust and torque range of operation. A small amount of engine friction data is included to facilitate the application of the propeller data.

*The Aerodynamic Drag of Five Models of Side Floats. N.A.C.A. Models 51-E, 51-F, 51-G, 51-H, and 51-J.* (R. O. House, N.A.C.A. Tech. Note No. 680, Dec., 1938.) (64/30 U.S.A.)

The drag of five models of side floats was measured in the N.A.C.A. 7 by 10-foot wind tunnel. The most promising method of reducing the drag of floats indicated by these tests is lowering the angle at which the floats are rigged. The addition of a step to a float does not always increase the drag in the flying range, floats with steps sometimes having lower drag than similar floats without steps.

Making the bow chine no higher than necessary might result in a reduction in air drag because of the lower angle of pitch of the chines. Since side floats are used primarily to obtain lateral stability when the seaplane is operating on the water at slow speeds or at rest, greater consideration can be given to factors affecting aerodynamic drag than is possible for other types of floats and hulls.

*Proposed Method for the Design of Bottom Plating for Flying Boat Hulls and Seaplane Floats.* (S. D. Berman, J. Aer. Sci., Vol. 6, No. 2, Dec., 1938, pp. 64-7.) (64/31 U.S.A.)

A lack of complete data for designing the bottom plating of flying boat hulls and floats prompted the author to investigate the subject of stresses in the plating

due to the normal pressures incurred while taking off or landing. In this undertaking, use was made of an approximate method of determining the stresses in thin plates given by Timoshenko. Since the dimensional requirements for adequate strength obtained by the author's application of Timoshenko's method are in close agreement with successful practice, the resulting design information is presented herewith in the hope that the designer will find it useful.

*N.P.L. Researches on the Stability of Aircraft.* (Engineering, Vol. 146, 4/11/38, pp. 527-8. Eng. Absts., Vol. 1, No. 11, Section 3, Dec., 1938, p. 203.) (64/32 Great Britain.)

Mathematically it has been shown that a model suspended at the end of a long rod can show the lateral stability characteristics of free flight under certain conditions as to correlation of mass, aerodynamic lift, and degrees of freedom. This method gives much quicker results than the laborious measurement of derivatives hitherto used. In a certain aircraft the loss of rolling moment with a highly tapered (4.4) wing was traced to body-wing interaction when the latter were in the low position, loss of stability not being due to the high taper as was thought at first. Wing-tip design to reduce undesirable rolling near stalling incidence is proving a difficult subject, wind tunnel research being very susceptible to scale effect in this instance. Slots are an effective remedy against wind dropping, but a design is being attempted which does not include them.

*The Dynamic Stability of a Helicopter Fitted with Hinged Rotor Blades.* (K. Hohenemser, Ing.-Arch., Vol. 9, No. 6, Dec., 1938, pp. 419-428.) (64/33 Germany.)

The author investigates the case of dynamic stability of a helicopter under hovering conditions. In the case of hinged blades perfect stability can in general not be obtained. It is, however, possible by means of certain design features (mass of rotating blades, inclination of rotor tip plane, aerodynamic moment about longitudinal axis of rotor blade, etc.) to increase the periodic time of self-induced oscillation of the helicopter and reduce the effect of the disturbance so that the aircraft is approximately in indifferent equilibrium. In the case of hinged blades, the gyroscopic effects of two rotors become additive, even if they rotate in opposite direction. A rotation of the helicopter about its axis is thus accompanied by a linear damping which is of the greatest importance for stability and control.

The successful flights of the Focke helicopter FW. 61 have shown that controlled stability is possible for rotors fitted with hinged blades.

*The Theory of Guide Vanes Applied to the Propeller.* (A. Betz, Ing.-Arch., Vol. 9, No. 6, Dec., 1938, pp. 435-452.) (64/34 Germany.)

The amount of rotary energy which can be abstracted from the propeller slipstream and converted into thrust depends markedly on the number of guide vanes fitted. At the same time the vanes must project considerably beyond the edge of the propeller slipstream in order to produce the greatest theoretical effect. As soon as the friction of the vanes is, however, considered, it pays to have shorter vanes fitted to a relatively large hub placed behind the propeller. In order to save introducing an extra hub, the guide vanes are best attached to suitable portions of the engine gondola which would in any case be subjected to the slipstream.

*A general Tank Test of a Model of the Hull of the P3M-1 Flying Boat, including a Special Working Chart for the Determination of Hull Performance.* (J. R. Dawson, N.A.C.A. Tech. Note No. 881, December, 1938.) (64/35 U.S.A.)

The results of a general tank test of a one-sixth full-size model of the hull of the P3M-1 flying boat (N.A.C.A. model 18) are given in non-dimensional form.

In addition to the usual curves, the results are presented in a new form that makes it possible to apply them more conveniently than in the forms previously used.

The resistance was compared with that of N.A.C.A. models 11-C and 26 (Sikorsky S-40) and was found to be generally less than the resistance of either.

*Characteristics of a Deflector Plate Flap.* (R. C. Molloy, Autom. Ind., Vol. 80, No. 3, 21/1/39, pp. 87-8.) (64/36 U.S.A.)

One form of this device consists of a simple slotted flap with a curved plate fixed to its leading edge which, with the flap in the undeflected position, nests in the slot and does not protrude into the airstream. With the flap deflected, the deflector plate forms an extension of the slot for directing the air over the flap. A slot door on the under surface of the aerofoil, operated in conjunction with the flap by suitable mechanism, is preferably used to reduce drag at high speeds. A considerable improvement in the maximum lift coefficient is claimed for the deflector—external aerofoil type—over either the conventional external aerofoil or the slotted type with deflector plate.

*North Atlantic Flights by German Lufthansa during* 1938. (Canadian Aviation, Vol. 11, No. 12, December, 1938, p. 16.) (64/37 Germany.)

The 28 scheduled trans-Atlantic flights covered the period July 21st-October 19th. The 13 return flights, Horta (Azores) and New York were made with three Ha. 139 seaplanes, each equipped with four Junkers Jumo 205 Diesel engines of 600 h.p. each.

The two non-stop flights, Berlin-New York and return were made by a Focke-Wulf F.W. 200 Condor (land plane) fitted with four B.M.W. 132 L. petrol engines of 750 h.p. each.

The flights Horta-New York and return were carried out at approximately weekly intervals.

From the time table it appears that the interval between successive flights by the same machine was a week or less on 18 occasions and amounted to a fortnight on five occasions. The crossing times were generally consistent within 10 per cent., the average time taken for Horta-New York being 15.5 hours, whilst the average return journey took 14 hours. This works out at 154 and 170 m.p.h. respectively.

The corresponding speeds on the Berlin-New York and return flights were 158 and 199 m.p.h. respectively.

*Flight Research on the Problem of Vapour Lock.* (N. F. Scudder, J. Aer. Sci., Vol. 6, No. 2, Dec., 1938, pp. 68-71.) (64/38 U.S.A.)

From the results of this investigation it is apparent that the relatively large amount of gas contained in solution becomes separated when the absolute pressure on the fuel is diminished by climbing to a high altitude if agitation, such as that from a fuel pump and relief by-pass, is present.

At moderate temperatures (15°F. above standard altitude temperatures) the dissolved gases are made up in large proportion of the constituents of air.

The elimination of most of the fittings and valves needed in a twin-engine aeroplane and the use of a large fuel line with " easy " bends did not noticeably improve the performance of the system. In the summer, fuel coolers gave some improvement, but in the winter none whatever.

The operation of carburettors in which mixture strength is controlled by means of float bowl suction is violently upset by the quantity of gas liberated from aviation fuel during a fast climb.

If a conventional pump is used, a vapour separator is necessary for proper operation of the type carburettor used during these tests. For operation to 26,000ft. the separator installed in the carburettor feed line gives perfect operation, and it is probably simpler, lighter, and more dependable than any system

in which a pump without a relief valve is used because of the complexity and cost of the equipment necessary with such a system.

*Engine and Fuel—Their Mutual Effect on Development of the Power Plant.* Review of Papers presented at the Augsburg Meeting, V.D.I. (G. Leunig, Z.V.D.I., Vol. 82, 3/12/1938, pp. 1401-1409.) (64/39 Germany.)

As appears from the following selection, the papers covered a wide range of subjects:—

(1) Testing of liquid fuels for spark ignition and compression ignition engines.
(2) The utilisation of high boiling fuels for Diesel engines.
(3) Gas generators.
(4) Means of increasing the power output of engines operating on gas fuel.
(5) The coal dust engine.
(6) Mixture formation in spark ignition and Diesel engines.
(7) Limitation in r.p.m. and m.e.p.
(8) Ignition lag and Diesel knock.
(9) Development of the two-stroke engine.
(10) Spark ignition engines using petrol injection.
(11) Light weight construction of large industrial Diesel engines.
(12) Motor car engines for continual high power output.

As regards item 10, (Petrol injections in spark ignition engines) the lecturer referred to experiments carried out at the D.V.L. since 1930. Injection takes place into the combustion space during the induction stroke, using a normal Diesel injection pump. A special fuel nozzle of the pintle type is used, giving a rotating jet of wide expansion. Position of fuel nozzle as well as timing of the injection are of importance. Increase in maximum power output up to 17 per cent. was realised (increase in volumetric efficiency). Alternately, using weak mixtures, the fuel consumption can be reduced 16 per cent. below the best carburettor setting. In the case of multi-cylinder engines, there is a marked improvement in slow running and pick up.

*Petrol Injection for Spark Ignition Engines.* (A. Labarthe, L'Aero., Vol. 31, No. 1601, 3/2/39, p. 7.) (64/40 France.)

The petrol injection can be carried out either into the induction pipe or into the cylinder. In the latter case the fuel may either be injected during the induction or during the compression stroke.

Early experiments in America were confined to injection in the induction pipe. This is relatively easy to realise and even in its simplest form shows certain important advantages over the carburettor. Injection into the engine cylinder is more difficult, but has been applied with success to the German Jumo 211 engine. In this engine injection is carried out during the induction stroke, the pump plunger being pressure lubricated in order to avoid seizure. A similar method of injection has been employed by the author on a Ricardo single cylinder engine using a standard Bosch injection pump and adding 5 per cent. lubricating oil to the fuel. (Recently a special pump has been designed which will handle pure petrol.)

These experiments were reported on in 1937 (see Abstract No. 64/41 below) and are now being continued, the injection taking place during the compression stroke. This timing is the most difficult to realise in practice. It has, however, a number of theoretical advantages (reduction of detonation tendency, possibility of weak mixture utilisation by stratification, cold air scavenging during the induction stroke) which, added to the inherent advantage of fuel injection (perfect distribution, etc.) render the scheme very attractive and worthy of the most careful consideration.

*Petrol Injection for Spark Ignition Engines.* (A. Labarthe and A. Ponomareff, Comp. Rend., Vol. 204, 3/5/37, pp. 1316-1318.) (64/41 France.)

It is well known that the mixture formation in compression ignition engines is a complicated process, the actual ignition starting in certain zones in the combustion chamber depending on the engine load.

In the case of spark ignition engines, matters are still further complicated by the fact that the combustion must always start at a fixed point: the sparking plug. It is thus essential that the proper mixture be at this exact locality at the instant the spark passes. There are two methods of ensuring this: Injection into the induction pipe and injection into the cylinder. The author utilised the latter method, injection being carried out either during the induction or during the compression stroke. The former method is favoured by the authors although the latter, if functioning properly, has the greater tendency to reduce detonation.

The experiment was carried out on a single cylinder unit developing 10 h.p. at 3,000 r.p.m. when fitted with a carburettor. The fuel injection produced an increase in h.p. over the whole speed range (1,500-3,000 r.p.m.) compared with the carburettor performance, the improvement varying between 12 and 17 per cent. At the same time a reduction in specific fuel consumption of the order of 7 per cent. could be realised under certain conditions. The great advantages of petrol injection are: Better distribution, better slow running and pick up, reduced fire and ice dangers.

*Testing of Air-Cooled Aero Engines.* (K. Madsen, E.T.Z., 2/2/39, pp. 121-5. Metropolitan Vickers Tech. News Bulletin No. 047, 10/2/39, p. 7.) (64/42 Germany.)

The author describes an installation for the testing of aero engines which employs two rigidly coupled three-phase asynchronous machines. The large six-pole machine has a rating of 1,200 brake h.p. at 1,050 r.p.m. and takes over the main load during braking; the smaller machine is a 12/6 pole, pole-changing type for starting and heating up the aero engine. By connecting the two machines together it is possible, in the six-pole connection, to raise the total output from 1,400 to 2,400 brake h.p. continuously between 1,050 and 1,750 r.p.m. The author also gives details of the cooling equipment, the control plant, protective apparatus, high speed braking system, and in conclusion discusses the economy of the measuring installation.

Illustrated with four diagrams and two photographs.

*Research on the Mechanism of Knock.* (A. Kochling, Z.V.D.I., Vol. 82, 24/9/38, pp. 1126-1134. Eng. Absts., Vol. 1, No. 10, Section 3, Nov., 1938, pp. 188-9.) (64/43 Germany.)

The mixture to be investigated was exploded electrically in the usual way in a cylindrical bomb 84 cm. long and 20 cm. in diameter after drying, pressure being measured by piezo-electric voltage generated in a quartz crystal, which was fed to an oscillograph via an amplifier, knock resonance being measured simultaneously, accuracy being 6-10 per cent. Curves are given for mixtures of (methane + air) and (propane + air) at 20°, (pentane + air) at 30°, (benzole + air) and (toluol + air) at 80°, for an initial pressure of 2.5 atm., showing the maximum amplitude of oscillation $k_{max}$ plotted against the air ratio $\lambda$ between 0.5 and 1.5. A certain correlation with the actual engine experience appears, provided that one compares not the peak value of $k_{max}$, but the values at $\lambda = 0.85$ customary in actual running. The unexpected conclusion is drawn that chemical constitution (and physical properties closely allied) appears to have little effect on detonation. Values of $k_{max}$, mean velocity of combustion $= r$, and maximum pressure attained $\pi$, are plotted for benzol $- O_2 - N_2$ mixtures of constant calorific value up to 50 per cent. $O_2$; the second and third quantities show smooth curves, but the maximum amplitude shows a marked narrow peak of 4.3 at a little below the $O_2$

content of the atmosphere. According to other investigators a knocking mixture burns smoothly when the $N_2$ is replaced by a noble gas; it appears that a definite rate of combustion is required for knocking oscillation. Of 30 different fuels investigated all had approximately the same velocity of combustion with the exception of $H_2$, $C_2H_2$, $CS_2$ and CO, which all show anomalous knocking properties.

*The Use of Liquefied Ammonia as a Motor Fuel in France.* (G. Benoist, Revue des Carburants Français, Vol. 1, No. 8-9, August-September, 1938, pp. 349-354.) (64/44 France.)

Liquefied ammonia is obtained synthetically from atmospheric nitrogen and hydrogen. The latter is extracted from coken oven or water gas or produced electrolytically. Electrolysis is favoured by the author in view of the excess hydro-electric power available in France. Roughly speaking, 1.2 kg. of liquefied ammonia are equivalent to 1 litre of petrol. Assuming an energy consumption of 13 kilowatt hours per kg. of ammonia, the equivalent of 250,000 tons of petrol should become available without extending present plants. When used in the engine the ammonia gas is first passed over a catalysor which decomposes about 5 per cent. of the gas into $H_2$. This acts as a primer in the subsequent combustion.

It is stated that the power output is practically the same as that obtained with petrol, the weight of the container being about 0.6 kg. per h.p. hour.

*Carburettor Icing.* (R. Sanders, J.S.A.E., Vol. 44, No. 1, Jan., 1939, p. 14.) (64/45 U.S.A.)

Heating the carburettor intake promotes detonation and this, together with the resultant reduction in volumetric efficiency, may lead to a serious drop in power.

The amount of heat required under icing conditions may be reduced by adopting the following precautions:—

(1) Use as weak a mixture as possible.
(2) Maintain full cruising power.
(3) Maintain as high a cruising altitude as possible.

*Improvements in Diesel Engine Lubricating Oils.* (U. B. Bray, C. C. Moore and D. R. Merrill, J.S.A.E., Vol. 44, No. 1, Jan., 1939, pp. 35-42.) (64/46 U.S.A.)

Improvements in design and performance of Diesel engines, together with a more widespread usage of the smaller-sized higher speed Diesel engines, have emphasised the inadequacy of ordinary straight mineral oils for this type of service. Marked progress has been made in overcoming the deficiencies of straight mineral oils through the use of soap type addition agents. Several brands of this general type of compounded oils are now available to Diesel engine operators. The properties exhibited by the soap compounded oils include:—(1) Detergency, which aids in preventing ring sticking; (2) high film strength, which reduces the danger of scuffing, scratching, or galling under adverse or severe conditions; (3) high degree of oiliness, which reduces wear under normal operating conditions; (4) low carbon-forming tendency; and (5) adequate crank-case stability, which promotes cleanliness of the engine and continuance of efficient lubrication.

*Torque Measurements in Flight.* (J. Salez, Pub. Sci. et Tech. du Ministere de l'Air, B.S.T., No. 82.) (64-47 France.)

The torque-meter consists of a Farman reduction gear in which the front (propeller) crown wheel instead of being clamped to the casing is able to undergo a small rotation. This rotation is prevented by the action of four plungers under oil pressure. The pressure required to " float " this gear wheel is thus a measure

of the torque transmitted. After calibration on the ground (which revealed an accuracy of the order of $\pm 1$ per cent.) the flight experiments were carried out on Potez 541 fitted with two Gnome-Rhone 14 K drs engines (800 h.p. each at 4,000 m.). During these tests the induction pressure was kept constant at 735 mm. up to 4,350 m. (full throttle). Above this altitude, the induction pressure gradually decreased to 650 mm. at 5,300 m. (maximum altitude of tests); the full throttle h.p. as measured with the torque meter was compared with the value calculated from the equation

$$W_a/W_o = [1 + 0.00035\ (760 - H_a)]\ (515/500) + t_a$$

when

$W_a$ = h.p. at altitude.
$W_o$ = h.p. on ground.
$H_a$ = atmospheric pressure at altitude (mm. of $Hg$).
$t_a$ = temperature at altitude °C.

Agreement was satisfactory up to 3,600 m. Beyond this altitude, the actual h.p. was appreciably greater, the supercharged height being 4,350 m. instead of 3,600 m. as estimated from throttling tests on the ground. The author attributes the difference to the compression ratio of the blower increasing with altitude (due to reduction in intake temperature) and to the ramming effect due to the speed of the aircraft.

*An Instrument for the Measurement of Anomalous Viscosity.* (C. F. Goodeve, J. Sci. Inst., Vol. 16, No. 1, January, 1939, pp. 19-27.) (64/48 Great Britain.)

A new form of viscometer is described in which the fluid is placed in a rotating container with a conical inner surface. A viscous drag is imparted to a coaxially suspended or pivoted inner cone, and the torque produced measured by means of a torsion wire or spring. The rate of shear is altered by a movement of one of the cones relative to the other along the axis, thus altering the separation between the moving surfaces. The instrument is especially designed for the measurement of anomalous viscosities. Very high rates of shear may be obtained without the occurrence of turbulent flow.

*New Methods of Measuring Liquids.* (Th. Schiel, Siemens Zeitschrift, Dec., 1938, pp. 506-15. Metropolitan Vickers Tech. News Bulletin No. 643, 13/1/39, p. 10.) (64/49 Germany.)

Apparatus for liquid measurement can be classified under two main types, viz., volume meters for continuous metering in units of volume (drum, piston and turbine meters) and through flow meters which indicate the through flow in units of volume per unit of time (pressure difference and float meters). The author describes these various types. Illustrated with 11 photographs and 10 diagrams.

*Creep Rates and Recovery at High Temperatures.* (H. Zschokke, Brown Boveri Review, Dec., 1938, pp. 247-61. Metropolitan Vickers Tech. News Bulletin, No. 645, 27/1/39, p. 1.) (64/50 Switzerland.)

The author discusses the influence of alloying, heat treatment and deformation on the creep limit and the extent to which the evaluation of the results depends on the method employed, showing the unreliability of extrapolation of results over a very long period. He shows the influence on the resultant creep elongation of the recovery of the steel when service is intermittent, by means of creep tests with interspersed periods of relief under both constant maintained temperature and falling temperature. He explains the recovery by consideration of the mechanism of deformation of the grain boundaries and crystals.

Illustrated with 15 diagrams and three tables.

*The Working of Wrought Copper and Brass.* (Machinist, 21/1/39, pp. 1101-2. Metropolitan Vickers Tech. News Bulletin No. 645, 27/1/39, p. 9.) (64/51 U.S.A.)

In this general review of modern practice in the working of copper and brass, the different forms of the materials and their mechanical properties are first discussed. The working of the metals is next reviewed, the article giving the approved methods of all processes such as hot and cold working, annealing, machining, drilling, reaming, tapping, grinding, cleaning, soldering and welding. Information as to the typical applications and physical characteristics of the various forms of the materials is also given in tabular form. Illustrated with six diagrams and seven tables.

*The Effective Width of Curved Sheet After Buckling.* (W. A. Wenzek, L.F.F., Vol. 15, No. 7, 6/7/38, pp. 340-4. Available as Translation T.M. 880.) (64/52 Germany.)

In stiffened shells under compression the carrying capacity of the buckled sheet between stiffeners can be accounted for by the introduction of an "effective width." The sheet is replaced by two assumedly buckling resistant sheet strips of such width $2\,b_R$, that their carrying capacity under a stress equivalent to the shortening at the sheet edge is the same as that of the buckled sheet panel. For sheets rigidly built in at the side this stress is equal to the edge stress of the sheet.

$$\rho_R \cdot 2\,b_R = \rho_m \cdot t$$

where $t$ = width of sheet and $\rho_m$ = mean stress.

The present report contains a description of experiments made for the purpose of ascertaining the effective width of circularly curved sheet under pure flexural stress.

A relation for the effective width of curved sheets is established. Comparisons with similar tests made by the D.V.L. show good agreement.

*Application and Testing of Transparent Plastics Used in Aircraft Construction.* (K. Riechers and J. Olms, Luftwissen, Vol. 5, No. 6, June, 1938, pp. 197-202. Available as Translation T.M. 881.) (64/53 Germany.)

The article deals with the mechanical and physical properties of four representative transparent plastic resins: Cellulose nitrate, cellulose acetate, polymer mixtures and polyacrylic esters.

After a short description of the method of manufacture, the standard D.V.L. tests on safety glass and transparent plastics are described.

These cover the following points:—

1. Optical tests.
2. Falling ball test.
3. Weathering.
4. Bending stress.

One of the difficulties of installing transparent plastic sheets in aircraft is the large coefficient of thermal expansion of the materials. A plastic sheet 1 m. long will thus shrink 5 mm. for a drop in temperature of 40°C., a similar length of aluminium only contracting 1 mm. The mounting adopted must therefore be capable of allowing a slip of this order.

*Modern Manufacturing Equipment of the Ernst Heinkel Aeroplane Works.* (A. Thormann and H. Jockisch, L.F.F., Vol. 15, Nos. 1 and 2, January, 1938, pp. 83-90. Available as Translation T.M. 882.) (64/54 Germany.)

This report contains a description of new methods of fabrication, new equipment, and special tools, with a view to supplying data for design from economical points of view, as well as to stimulate the interest of other factories in improved shop methods.

The following aspects of the problem are considered:—

1. Method and tools for changing the sectional shape of light alloy and steel tubes.
2. Skin riveting.
3. Automatic strip insertion for drawing sheet sections.
4. Panel beating tool (silent).
5. Beam strap milling machine.
6. Drilling and countersinking tools for mounting standard parts.
7. Tools for creasing thin sheet.

*On the Luders-Hartman Lines of Slip at the Yield Point.* (E. Reuss, Z.A.M.M., Vol. 18, No. 6, Dec., 1938, pp. 347-357.) (64/55 Germany.)

The author considers the formation of slip surfaces in an elastic body at the yield point. These lines of slip can be rendered visible by etching the surface and are known as Luders-Hartman lines.

As a typical example, the case of an elastic cylinder is investigated and it is shown that regions of plastic flow must exist, which by Castigliano's principle, are portions of planes parallel to the axis of the cylinder. The stress distribution of the material and especially the discontinuity at the slip surface may be calculated by means of a logarithmic potential.

*Relaxation Methods Applied to Problems Relating to Elastic Stability and Vibrations.* (K. N. E. Bradfield, D. G. Christopherson and R. V. Southwell, Proc. Roy. Soc., Series A, Vol. 169, No. 938, pp. 289-316.) (64/56 Great Britain.)

Preceding papers in this series have been concerned with unique solutions; this paper deals with problems such that a complete solution would define an infinite number of configurations, all satisfying the governing equations and the terminal conditions, but each associated with some particular value of a critical loading or frequency (the " characteristic number " or " Eigenwert "). The strut and vibrating rod (of non-uniform section) have been chosen for detailed treatment as the simplest examples, respectively, of elastic stability and vibrations; but the principles as distinct from the details of the relaxation treatment are quite general, and they provide a new method of attack on problems which are at once difficult and important.

In both problems relaxation methods appear capable of determining, with more than sufficient accuracy for practical purposes (when dimensions, etc., are not known exactly), not only characteristic numbers but also the mode associated with each. (The modes are not determined by the well-known method of Lord Rayleigh.)

*Noise from Propellers with Symmetrical Sections at Zero Blade Angle. II.* (A. F. Deming, N.A.C.A. Tech. Note No. 679, Dec., 1938.) (64/57 U.S.A.)

In a previous paper (Technical Note No. 605), a theory was developed that required an empirical relation to calculate sound pressures for the higher harmonics. Further investigation indicated that the modified theory agrees with experiment and that the empirical relation was due to an interference phenomenon peculiar to the test arrangement used.

Comparison is made between the test results for a two-blade arrangement and the theory. The comparison is made for sound pressures in the plane of the revolving blades for varying values of tip velocity. Comparison is also made at constant tip velocity for all values of azimuth angle $\iota$.

A further check is made between the theory and the experimental results for the fundamental of a four-blade arrangement with blades of the same dimensions as those used in the two-blade arrangement.

CONCLUSIONS.

1. The theory gives the sound pressure with fair accuracy for the purpose for the first five harmonics of a two-blade arrangement with symmetrical sections exerting zero thrust for values of $V_0/c$ up to 0.80.

2. The effect of blade thickness of propellers alone in producing noise is small except for low angles of attack.

3. The derived relationships give a good approximation to the polar distribution of the rotation noise for the first four harmonics.

*Electric Model Tests for Solving Heat Flow Problems.* (F. Bruckmayer, Archiv für Warmewirtschaft, January, 1939, pp. 23-5. Metropolitan Vickers Tech. News Bulletin No. 644, 20/1/39, p. 9.) (64/58 Germany.)

The author describes a method for the solution of heat flow problems by means of comparative electrical measurements on models. An imitation of the particular part is cut out of thin metal foil (tinfoil), current being supplied by means of copper bars to the parts of the model which represent the heat conducting surfaces; the electrical conductivity of this two-dimensional model is determined from the current flow and voltage drop. Tests on tubes, hollow stones and girders, are described and it is suggested that the method may render possible more accurate determination of the heat losses or temperature course in the case of fittings, flanges, machine parts, etc.

Illustrated with five photographs and four diagrams.

*Visual Examination of Temperature Fields by Means of Temperature-Sensitive Coloured Paints.* (F. Penzig, Z.V.D.I., Vol. 83, No. 3, 21/1/39, pp. 69-74.) (64/59 Germany.)

The idea of using substances which change colour with change in temperature as indicators is not new. The difficulty is to obtain materials which give permanent records on subsequent cooling and which are at the same time sensitive and accurate. The problem was solved by the Oppau Research Laboratory of the I.G. by the use of certain metallic salts which change their composition at certain critical temperatures (evolving water, $CO_2$, ammonia, etc.), this break up being accompanied by a characteristic change in colour. Over 300 combinations of salts were investigated before the final 12 indicators were evolved. These cover a range from 30°C. to over 400°C., the accuracy of the record being generally of the order of $\pm 5$°C. The work is being extended to cover temperatures up to 650°C.

The paint is made by mixing finely divided resin with the powdered salt and adding alcohol to obtain the required consistency. The thickness of the applied layer is of the order of 0.05 mm. and is negligible in heat transfer experiments. The method of colour indication has been successfully applied to the study of temperature distribution on aircraft engine cylinders, and examples in the form of colour photographs are given in the article.

Other possible applications are briefly discussed.

*Application of the Harvard Meteorograph to a Study of Icing Conditions.* (K. O. Lange, J. Aer. Sci., Vol. 6, No. 2, Dec., 1938, pp. 59-63.) (64/60 U.S.A.)

Routine radio soundings since December, 1936, have yielded cases in which ice formation greatly affected the ascensional rate of the balloons. In several instances they were forced into a rapid descent of several thousand feet before the ice melted off. From the changes of the rate of ascension, the amount of ice formation can be computed, *i.e.*, radio soundings indicate the existence and amount of icing in the atmosphere.

Present samples of such radio soundings indicate the formation of an amount of ice of the order of magnitude of one kilogramme. It formed suddenly and occurred in layer of a steep temperature lapse rate at temperatures slightly above

the freezing point and at relative humidities of less than 100 per cent. Rapid formation of large quantities of ice near the temperature of the freezing point can be explained only if the way in which the heat of fusion is extracted can be determined. The radio meteorograph records show that the air was not saturated, allowing rapid evaporation of part of the cloud or rain drops after they hit the balloon. The amount of heat absorbed by this process is sufficient to change considerable amounts of liquid water into ice in a relatively short time. The observational material presented in this paper indicates that relative humidities of less than 100 per cent. are a pre-requisite for dangerous ice formation.

Blue Hill Observatory proposes to conduct a systematic study of the mechanics of ice formation by means of successive radio soundings on days when the regular early morning ascents show icing and by expansion of the rime studies on Mount Washington.

*Instructional Films on the Subject of Conformal Representation.* (H. Heinrich, Z.A.M.M., Vol. 18, No. 6, Dec., 1938, p. 366. Göttingen Mathematical Congress.) (64/61 Germany.)

Two films have so far been prepared, dealing respectively with the image function $w=\frac{1}{2}$ and $w=z+1/z$ (Joukowsky transformation), whilst a third film deals with the correlated streamlines round image circle and wing profile. The correlated curves are drawn with pencil on tracing paper, divided into small corresponding sections and inked in progressively. During this process the paper is illuminated from below and photographed from above. As neither paper nor camera are shifted between successive exposures, no difficulty in accurate superposition arises.

*The Nature of Sliding and the Analysis of Friction.* (F. P. Bowden and L. Leben, Proc. Roy. Soc., Series A, Vol. 169, No. 938, 7th February, 1939, pp. 371-391.) (64/62 Great Britain.)

A detailed analysis of the kinetic friction between moving metals shows that the frictional force does not remain constant during sliding. Sliding is not a continuous process; the motion proceeds in jerks and large and violent fluctuations occur in the friction. In the case of dissimilar metals the top surface sticks to the bottom one and moves with it until, as a result of the gradually increasing pull, a sudden and very rapid slip occurs. The process is then repeated indefinitely. A simultaneous measurement of the surface temperature shows that this too is fluctuating and, at the instant of slip, there is a sudden temperature "flash."

The exact behaviour depends upon the relative physical properties of the metals, particularly on the melting point, and there is evidence that three distinct types of sliding may occur. The experiments suggest that friction is due to a welding together of the metals at the local points of contact. These metallic junctions are large compared with the dimensions of a molecule and when they are broken the metal is distorted to a considerable depth.

Even if the surfaces are lubricated with mineral oils or other lubricants an intermittent clutching and breaking away of the surfaces occurs and the behaviour may be essentially the same. Certain long chain fatty acids may prevent stick-slip and allow continuous sliding to take place.

*Area of Contact Between Stationary and Between Moving Surfaces.* (F. P. Bowden and D. Tabor, Proc. Roy. Soc., Series A, Vol. 169, No. 938, 7th February, 1939, pp. 391-413.) (64/63 Great Britain.)

An estimate of the real area of contact between stationary and between moving and metal surfaces has been made by electrical and by visual means. Experiments with stationary surfaces show that the area of intimate contact is very small. It

varies with the pressure, but for flat steel surfaces it may be less than one ten-thousandth of the apparent area. The real area of contact is not greatly affected by the size, shape and degree of roughness of the surface; it depends mainly on the pressure. The general behaviour is consistent with the view that the surfaces are held apart by small irregularities. This means that even with lightly loaded surfaces the local pressure may be sufficiently great to cause steel to flow plastically. This conclusion is supported by the observed relation between the pressure and the electrical conductance.

Measurements made with moving surfaces show that the area of contact is not constant, but is fluctuating rapidly during sliding. A detailed analysis shows a remarkable correlation between these fluctuations and the frictional and temperature changes described in an earlier paper. It is clear that an intermittent clutching and breaking away of the surfaces is taking place and the results support the view that metallic junctions between the metals are being rapidly formed and broken.

The conductance measurements show that even if the metals are lubricated with mineral oils and other lubricants, metallic contact may still occur through the film of lubricant.

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## LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the supply of copies of translations mentioned below should be addressed to the Under-Secretary of State (R.T.P.), Berkeley Square House, W.1, and will be supplied, free of charge, as far as availability of stocks permit. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

| TRANSLATION NUMBER AND AUTHOR. | TITLE AND JOURNAL. |
|---|---|
| | AERODYNAMICS AND HYDRODYNAMICS. |
| X20 Birnbaum, W. ... | *The Two-Dimensional Problem of the Beating Wing.* (Z.A.M.M., Vol. 4, 1924.) |
| 828 Meissner, W. ... | *Measurement of the Temperature of High Speed Gas Flow.* (Forschung, Vol. 9, No. 5, Sept.-Oct., 1938, pp. 213-8.) |
| 830 Possio, C. ... ... | *Aerodynamic Forces on an Oscillating Profile in a Compressible Fluid at Sub-Sonic Speed.* (Volume Commemorativo del XXV Annuale del Laboratorio di Aeronautica de R. Politecnico di Torino, 1938, pp. 152-169.) |
| | AIRCRAFT. |
| 805 Nemchinov, V. ... | *Choice of Optimum Altitude and Régime of Flight.* (Civil Aviation, U.S.S.R., Vol. 8, No. 6, June, 1938, pp. 15-18.) |
| 816 Langheinrich, M. ... | *Load Specifications as Affected by Experience Obtained by the Lufthansa with Float Seaplanes.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 339-41.) |

| TRANSLATION NUMBER AND AUTHOR. | | TITLE AND JOURNAL. |
|---|---|---|
| 817 | Van der Maas, H. J. | *Some Notes on the Measurement of the Flying Qualities of Aircraft.* (Lecture delivered at the Istus Congress, Berne, 1938.) |
| 829 | Santangelo, S. G. ... | *Flight in Gusty Air.* (L'Aerotecnica, Vol. 18, No. 4, April, 1938, pp. 472-94.) |
| | | INSTRUMENTS. |
| 811 | Thum, A. ... ... Svenson, O. ... ... Weiss, H. ... ... | *Modern Extensometers.* (Forschung, Vol. 9, No. 5, Sept.-Oct., 1938, pp. 229-34.) |
| 821 | Chlingensperg, R. von | *A New Device for the Measurement of Take-off.* (Luftwissen, Vol. 5, No. 11, November, 1938, pp. 417-20.) |
| 825 | Henschel ... ... | *Henschel Control Force Indicator.* (Kaempf System. German Patent 630,368.) |
| | | ENGINES. |
| 814 | Helmbold, T. ... | *The Effect of Altitude on the Cooling of Engines.* (L.F.F., Vol. 15, No. 7, 6th July, 1938, pp. 354-67.) |
| 819 | Leist, K. ... ... | *Problems Connected with the Construction of Exhaust Gas Turbines.* (L.F.F., Vol. 15, No. 10-11, 10th October, 1938, pp. 481-94.) |
| | | MATERIALS. |
| 812 | Giehmann, H. ... | *Surface Protection of Electron. Protection of High Strength Malleable Magnesium Alloys from Corrosion.* (Korrosion und Metallschutz, Vol. 14, No. 1, January, 1938, pp. 9-13.) |
| 813 | Sterner-Rainer, R. ... | *Corrosion Tests of Cast Magnalium Specimens Under Tension in Different Agents.* (Korrosion und Metallschutz, Vol. 14, January, 1938, pp. 13-18.) |
| | | METEOROLOGY. |
| 822 | Brun, E. ... ... | *Distribution of Temperature Over an Aeroplane Wing—Application to the Phenomena of Ice Formation.* (Pub. Sci. et Tech. No. 119, 1938.) |
| 824 | Mironovitch, V. ... Viaut, A. ... ... | *Turbulence and Aerial Navigation in the Sub-Stratosphere.* (l'Aeronautique, Vol. 20, No. 233, October, 1938, pp. 202-6.) |
| | | ARMAMENTS. |
| 802 | Kourensky, M. M. ... | *Movement of a Projectile in a Medium of Variable Density.* (Mémorial de l'Artillerre Française, Vol. 16, No. 3, 1937, No. 63, pp. 753-66.) |
| 806 | Rugicka, J. ... ... | *Review of a Paper on the Effect of Projectiles and Bombs on Concrete.* (Z.G.S.S., Vol. 33, No. 5, May, 1938, pp. 141-142.) |

| TRANSLATION NUMBER AND AUTHOR. | | TITLE AND JOURNAL. |
|---|---|---|
| 808 | Oerlikon ... ... | *Electro-hydraulic Device for Pointing Aircraft Guns (Oerlikon).* (Luftwehr, Vol. 5, No. 5, May, 1938, pp. 203-4.) |
| 818 | Baranski, G. .. | *Aircraft Guns. Questions Relative to Design and Tactical Employment.* (Luftwissen, Vol. 5, No. 5, May, 1938, pp. 157-163.) |
| | | WIRELESS. |
| 782 | Kiruschenkov .. | *Simplified Method for Determining the Computed Position of an Aeroplane from Two Radio Bearings.* (Air Fleet News, U.S.S.R., No. 7, July, 1938, pp. 60-5.) |
| 810 | Dallenbach, W. ... Kleinsteuber, W. ... | *Reflection and Absorption of Decimetre Waves on Plane Dielectric Surfaces.* (H.F. Technik, Vol. 51, No. 5, May, 1938, pp. 152-6.) |

# THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

## SEVENTY-FOURTH ANNUAL REPORT OF THE COUNCIL.

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MEMBERSHIP.

The Membership of the Society for 1938 shows a net increase, after allowing for members suspended, of 248 over 1937. The figures in brackets give the membership in 1937.

For the first time in the history of the Society the membership has exceeded 2,000. It is of interest to note some dates in the growth of membership. The Society was founded in 1866 and at the end of that year had a membership of 65. In 1903 the membership rose to 102. By the middle of 1914 it was still less than 500. During the war period the membership figure reached a maximum of 1,146 in 1919 and then dropped steadily to 630 in 1925. From that year, however, the membership has been rising regularly, reaching 1,038 in 1927 (when the Institution of Aeronautical Engineers amalgamated with the Society), 1,503 in 1934 and 2,140 (excluding suspended members) in 1938.

The Council have under earnest consideration how the membership can be further increased so as to include many in the industry who are not at present members.

| | No. of Members. | | Honorary & Life Members. | | Suspended. | | Total. | |
|---|---|---|---|---|---|---|---|---|
| Fellows ... ... ... | 167 | (156) | 22 | (20) | 1 | (2) | 190 | (178) |
| Members ... ... ... | 50 | (55) | 1 | (1) | 1 | (1) | 52 | (57) |
| Associate Fellows ... ... | 673 | (612) | 5 | (5) | 15 | (7) | 693 | (624) |
| Associate Members... ... | 184 | (156) | — | (—) | 6 | (6) | 190 | (162) |
| Associates ... ... ... | 256 | (236) | 3 | (3) | 15 | (15) | 274 | (254) |
| Graduates ... ... ... | 70 | (25) | — | (—) | — | (—) | 70 | (25) |
| Companions ... ... ... | 113 | (116) | 10 | (10) | 6 | (8) | 129 | (134) |
| Founder Members ... ... | 22 | (24) | 1 | (1) | — | (1) | 23 | (26) |
| Students ... ... ... | 550 | (468) | — | (—) | 47 | (38) | 597 | (506) |
| Temporary Hon. Members | — | (—) | 38 | (30) | — | (—) | 38 | (30) |
| | 2085 | (1848) | 80 | (70) | 91 | (78) | 2256 | (1996) |
| *Less* Joint Members ... | 25 | (26) | | | | | 25 | (26) |
| | 2060 | (1822) | 80 | (70) | 91 | (78) | 2231 | (1970) |

DONATIONS.

The Council have to thank the Air Ministry for the fourteenth year in succession for their generous grant of £250 to the Funds of the Society, and the Society of British Aircraft Constructors, also for the fourteenth year in succession, for a similar donation.

The President and Council have, during the year, had under constant review the necessity for increasing the Funds of the Society. They have very fully realised that substantial donations must depend upon a progressive policy which will be of active benefit to both the engineering and scientific sides of aviation and be able to cope with the rapidly increasing expansion of the industry. Certain lines of future activities have already been laid down, and the Council will welcome any constructive suggestions from members to increase the usefulness as well as the prestige of the Society.

ENDOWMENT FUND.

The table below gives the progress of the Endowment Fund:—

| | £ | s. | d. |
|---|---|---|---|
| December, 1926 ... ... ... ... | 575 | 0 | 0 |
| December, 1927 ... ... ... ... | 597 | 2 | 0 |
| December, 1928 ... ... ... ... | 1,047 | 18 | 0 |
| December, 1929 ... ... ... ... | 1,077 | 6 | 0 |
| December, 1930 ... ... ... ... | 1,265 | 10 | 0 |
| December, 1931 ... ... ... ... | 1,935 | 10 | 0 |
| December, 1932 ... ... ... ... | 2,196 | 2 | 0 |
| December, 1933 ... ... ... ... | 9,716 | 19 | 5 |
| December, 1934 ... .. ... ... | 10,131 | 14 | 11 |
| December, 1935 ... .. .. ... | 10,895 | 10 | 7 |
| December, 1936 ... ... ... ... | 11,138 | 16 | 7 |
| December, 1937 ... ... ... ... | 11,474 | 3 | 7 |
| December, 1938 ... ... ... ... | 12,211 | 12 | 11 |

The Endowment Fund Trust Deed specifically ensures that every contribution to the Fund will be devoted to the provision of the Society's own building.

The Council have great pleasure in announcing that new headquarters for the Society have been acquired at No. 4, Hamilton Place, W.1. The new headquarters will be in keeping with the increasing activities of the Society, and will provide those facilities for members which, due to lack of the necessary capital, have not been provided in past years. The Library will undoubtedly be one of the finest rooms of its kind, enabling the Society's unique collection of aeronautical books to be displayed to their fullest advantage and of easy access to members.

The new Headquarters will be taken over on March 25th and will be formally opened on June 16th, 1939.

LIBRARY.

Mr. J. E. Hodgson, Hon. F.R.Ae.S., has acted as Honorary Librarian for the past fifteen years and the Council wish to place on record their appreciation of the valuable advice and help he has given about all matters pertaining to the Library.

Mr. Hodgson's advice has proved particularly valuable in the preliminary arrangements for the new library at No. 4, Hamilton Place, and under his guidance the Council are confident that members will make a rapidly increasing use of the new facilities which will be available. In view of the increasing work in connection with the Library it has become necessary to appoint a full time librarian.

The Council particularly wish to thank those members who have helped to enrich the Society's Slide and Photographic Collections, which are now a valuable

means of propaganda. During the year over 3,000 slides were lent to members and others for lecture purposes.

GARDEN PARTY.

The Society held its annual Garden Party on Sunday, May 8th, 1938, at the Great West Aerodrome, near Hayes, the use of which was kindly given to the Society for the day by Mr. C. R. Fairey, M.B.E., F.R.Ae.S., a former President. The attendance of members and their friends was the largest since the function was first inaugurated. Over 4,000 members and guests were present.

The whole of the arrangements on the aerodrome were, as in previous years, carried out by Mr. Fairey and his staff, and the Council wish to pay a tribute to the excellent organisation which allowed the whole programme to be carried through so efficiently. It is very largely due to the really practical and generous help of Mr. Fairey that the Garden Party has become the outstanding aeronautical function of the year.

The Council would like to express their high appreciation of the help given by Flight Lieutenant C. S. Staniland and those under him. They were entirely responsible for the flying programme and the arrangements for the static display.

The following programme was arranged:—

2.30—3.0 p.m.—Reception by the Vice-President, Mr. F. Handley Page, and Mrs. Handley Page.
3.00—3.08 p.m.—Mr. R. L. Porteous. Chilton.
Mr. P. B. Elwell. Taylor Club.
3.10—3.18 p.m.—Mr. J. Summers. Wellesley.
3.20—3.28 p.m.—Captain E. W. Percival. Q 6.
Mr. D. M. Bay. Vega Gull.
3.30—3.38 p.m.—Mr. H. W. Skinner. R.R. Trainer.
3.40—3.48 p.m.—Mr. D. L. Hollis-Williams. Monospar with experimental undercarriage.
Mr. M. Lacayo. Schelde Musch.
3.50—3.58 p.m.—Mr. C. S. Staniland. P4/34.
4.00—4.08 p.m.—Mr. A. H. C. A. Rawson. Kay Gyroplane.
4.10—4.38 p.m.—Tea interval. (During the tea interval there was a demonstration of the winch-launching of sailplanes by members of the London Gliding Club.)
4.40—4.48 p.m.—Captain C. F. Uwins. Blenheim.
4.50—5.18 p.m.—Tea interval. (During the tea interval there was a demonstration of the following early aircraft):—
Mr. R. G. J. Nash. 1911 Gordon Bennett Bleriot or 1909 Type II Bleriot.
Squadron Leader A. N. Wheeler. Sopwith Pup.
Mr. A. J. Edmunds. Deperdussin.
Mr. R. O. Shuttleworth. Bleriot.
5.20—5.28 p.m.—Mr. H. J. Penrose. Lysander.
5.30—5.38 p.m.—Mr. Brian Allen. Tipsy Two-Seater.
Captain Birkett. Tipsy Two-Seater.
Mr. Ward. Tipsy Two-Seater.
5.40—5.48 p.m.—Mr. G. N. Wikner. Wicko.
5.50 p.m.—Durasteel Roofs, Ltd. Anti-fire demonstration.

Dr. Neville Whitehurst was in attendance during the afternoon as the Medical Officer on the Aerodrome.

The following machines, in addition to those of private owners arriving by air, were on the aerodrome, including those which gave demonstrations during the afternoon:—

Arpin Monoplane. (M. B. Arpin.)
Bristol Blenheim. (Bristol Aeroplane Co., Ltd.)
Cygnet Minor. (C.W. Aircraft.)
Chilton Monoplane. (Chilton Aircraft, Ltd.)
De Havilland 86B. (De Havilland Aircraft Co., Ltd.)
De Havilland Dragon Rapide. (De Havilland Aircraft Co., Ltd.)
De Havilland Tiger Moth. (De Havilland Aircraft Co., Ltd.)
Fairey Battle. (Fairey Aviation Co., Ltd.)
Fairey Swordfish. (Fairey Aviation Co., Ltd.)
Fairey P.4/34. (Fairey Aviation Co., Ltd.)
The Wicko Monoplane. (Foster, Wikner Aircraft Co., Ltd.)
Monospar. (General Aircraft Ltd.)
Monospar—Tricycle Chassis. (General Aircraft Ltd.)
Marendaz Mk. III. (International Aircraft and Engineering Co., Ltd.)
Kay Gyroplane (Type 331). (Kay Gyroplane Ltd.)
The Luton Buzard. (Luton Aircraft Ltd.)
Bleriot Monoplane, 1909. (R. G. J. Nash.)
Miles Monarch. (Phillips and Powis, Ltd.)
Miles Magister. (Phillips and Powis, Ltd.)
Percival Q6. (Percival Aircraft Ltd.)
Percival Vega Gull. (Percival Aircraft Ltd.)
Lockheed 12A. (Brian Allen Aviation Ltd.)
Bleriot XIV. (R. O. Shuttleworth.)
Deperdussin Monoplane, 1911. (R. O. Shuttleworth.)
Hanriot Biplane (1917). (R. O. Shuttleworth.)
Sopwith Pup. (R. O. Shuttleworth.)
Short Scion Senior. (Short Brothers.)
Schelde Musch Aircraft. (Koninklijke Maatschappij.)
Stinson Reliant. (Stinson Aircraft Corporation.)
Tipsy S2. (Tipsy Light Aircraft Co.)
Tipsy B. (Tipsy Light Aircraft Co.)
Vickers Wellesley. (Vickers Aviation Ltd.)
Taylor Cub Everel Airscrew. (A. J. Waller.)
Westland Lysander. (Westland Aircraft Ltd.)
The Monospar Ambulance. (General Aircraft Ltd.)
Experimental Apparatus. (W. E. Gray.)
Horden Richmond Autoplane. (Duke of Richmond.)
Minimoa. (P. A. Wills.)
H.17 Sailplane. (Amy Johnson and John Soffery.)
Gull. (Slingsby, Russell and Brown, Ltd., and Dudley Hiscox.)
Vickers Wellington I. (Vickers Aviation, Ltd.)
Cadet.
Taylorcraft. (Continental.)
Kirby Kite. (————————.)
Short " Empire " Flying Boat. (Short Brothers.) (Imperial Airways.)

The Council wish to record their thanks to all those pilots, firms and others who so willingly helped with the display of the above aircraft.

The Council also wish to record their thanks to Mr. W. Courtenay, M.M., A.R.Ae.S.I., who gave a broadcast description of the events during the afternoon; to the Automobile Association for their organisation of the car and aeroplane park and preparation of a map showing how to reach the aerodrome, and to Messrs. L. A. Rumbold and their organisation in the aircraft park.

A Static Display was given in one of the hangars, and the Council wish to thank the following for their assistance in making the display of such interest during the afternoon:—

Aircraft metals, shown by Accles and Pollock, Ltd.; retractable undercarriage and a pre-selector control, shown by Aircraft Components, Ltd.; Cheetah IX engine, shown by Armstrong-Siddeley Motors, Ltd.; hydraulic aircraft equipment, shown by Automotive Products, Ltd.; hydraulic equipment and brakes, shown by Avery Equipment, Ltd.; asbestos suits and screens, shown by Bell's Asbestos and Engineering Supplies, Ltd.; bakelite in aircraft, shown by Bakelite Ltd.; aircraft brakes, shown by Bendix Ltd.; riveting machines, shown by the Bifurcated and Tubular Rivet Co., Ltd.; the Aquila, Pegasus XVIII and aero engine components, shown by the Bristol Aeroplane Co., Ltd.; bakelite composition, shown by J. Burns, Ltd., in conjunction with Bakelite, Ltd.; aero-mixture indicating outfit, shown by Cambridge Instrument Co., Ltd.; aircraft dopes and finishes, shown by Cellular, Ltd.; controllable pitch airscrews and De Havilland Gipsy Major I engine, shown by De Havilland Aircraft, Ltd.; portable tools, shown by Desoutter Bros., Ltd.; aircraft tyres, shown by Dunlop, Ltd.; bomb shelters and steel roofing, shown by Durosteel Roofs, Ltd.; steels in aircraft, shown by Thos. Firth and John Brown, Ltd.; airscrews, shown by the Fairey Aviation Co., Ltd.; stainless steel in aircraft, shown by Firth-Vickers Stainless Steels, Ltd.; aircraft radiators, shown by Gallay, Ltd.; light alloys, shown by High Duty Alloys, Ltd.; welded materials, shown by Harborough Aircraft Construction Co., Ltd.; aircraft accessories, shown by Grice and Young; motor control carburettor, shown by H. M. Hobson (Aircraft and Motor) Components, Ltd.; aircraft fittings of Perspex, shown by Imperial Chemical Industries, Ltd.; Marlbrite, Ltd.; airscrews, shown by Jablo Propellers, Ltd.; aircraft instruments, shown by Kelvin, Bottomley and Baird, Ltd.; aircraft radio, shown by Marconi Wireless Telegraph Co., Ltd.; Napier-Halford Dagger, Series III, shown by D. Napier and Son, Ltd.; air raid shelters, shown by Nissen Building, Ltd.; wheel and brake equipment, shown by the Palmer Tyre, Ltd.; oil cooler, shown by Robertson Oil Coolers, Ltd.; protective airscrew covering, shown by Raymond Manufacturing Co., Ltd.; Merlin engine, shown by Rolls-Royce, Ltd.; electrical equipment, shown by Rotax, Ltd.; model of airship L.Z. 130, shown by Captain J. A. Sinclair; aircraft instruments, shown by Smith's Aircraft Instruments; automatic pilot and gyrorison, shown by the Sperry Gyroscope, Ltd.; model aircraft, shown by Vickers (Aviation), Ltd.; lubrication equipment, shown by Tecalemit, Ltd.

The Council would like to place on record their thanks for the help given by the Air Council in granting permission for certain service machines to be present at the display and to take part in it; and to the Fairey Aviation Co., Ltd., for their permission for the Works Silver Band of the Fairey Aviation Company, Ltd. (Stockport Branch) to play during the afternoon, under the leadership of Mr. P. Smith.

### Annual General Meeting.

The following is an abbreviated report of the Annual General Meeting of the Society, held on Thursday, March 31st, 1938, in the Library, at 7, Albemarle Street, London, W.1, at 6.30 p.m.

*Present*:

Mr. F. Handley Page (Vice-President) in the chair.

Miss A. Baden-Powell (Honorary Companion).
Major C. J. P. Ball (Associate Fellow).
Mr. Griffith Brewer (Honorary Fellow).
Miss Frances M. Buss (Companion).
Mr. J. D. Campbell (Associate Fellow).
Miss L. Chitty (Fellow).
Mr. C. Cooper (Associate Fellow).
Mr. H. Roxbee Cox (Fellow).
Mr. W. C. Devereux (Fellow).
Mr. C. R. Elgie (Associate).
Mr. G. A. F. Embleton (Companion).
Mr. E. C. Gordon England (Fellow).
Miss R. King Everard (Companion).
Mr. W. E. Gray (Companion).

Professor F. T. Hill (Fellow and Member).
Miss Alice Kennedy (Companion).
Flt. Lieut. R. C. Preston (Associate Member).
Major B. W. Shilson (Fellow).
Miss A. G. Stewart (Companion).
Mr. B. W. Townshend (Fellow).
Mr. G. O. Waters (Associate).
Mr. Lawrence Wingfield (Solicitor).
Mr. Norman Smith (Hon. Accountant).
Captain J. Laurence Pritchard (Secretary).

1. The Secretary read the notice convening the meeting.

2. The Chairman asked those members present to make any comments they wished on the Report of the Council for the year 1937-1938 as published in the Journal for March, 1938. No comments were forthcoming and the President moved that the Report be adopted.

3. The Chairman read the Report of the Scrutineers for the Council Ballot, resulting in the election to the Council of the following members:—

Professor L. Bairstow.
Mr. Griffith Brewer.
Mr. S. Camm.
Mr. W. C. Devereux.
Mr. A. H. R. Fedden.
Mr. A. Gouge.
Mr. F. Handley Page.
Professor A. J. Sutton Pippard.
Lord Sempill.
Mr. C. C. Walker.

A vote of thanks to the Scrutineers, Mr. H. Roxbee Cox, Professor F. T. Hill, and Mr. W. O. Manning, for their work was proposed by the Chairman. Mr. W. C. Devereux seconded the vote of thanks.

4. It was proposed by Mr. E. C. Gordon England and seconded by Mr. W. O. Manning that Messrs. Price, Waterhouse be re-elected Auditors of the Society's accounts for the ensuing year.

The Chairman proposed a hearty vote of thanks to Mr. Norman Smith for his useful work in connection with the Society's accounts and the improved method in which they were presented.

5. Mr. W. E. Gray (Companion) raised the question of the Society's medals and awards and the Chairman outlined the procedure.

Mr. Gray then referred to the question he had raised at the last Annual General Meeting regarding the speeding up of publication of results of public research. After a full discussion Mr. Gray submitted the following resolution which Mr. E. C. Gordon England seconded:—

> "That this meeting calls on the Council to use its utmost influence with the Air Ministry to get the accepted recommendation No. 11 of the Gorell Committee Report put into effect."

The resolution was agreed to by the meeting.

Mr. Handley Page welcomed to the meeting Miss Agnes Baden-Powell, who had recently been made an Honorary Companion. He would like to thank her for the kindly thought which prompted her to suggest presenting a prize in memory of her brother, the late Major B. F. S. Baden-Powell, a former President of the Society. Miss Baden-Powell helped her brother in his early experiments with kites and balloons.

Miss Baden-Powell replied that she considered it a great privilege to belong to the Society and she thanked Mr. Handley Page for his kind remarks.

The meeting then terminated.

MR. H. E. WIMPERIS, C.B., C.B.E., M.A., M.I.E.E., F.R.Ae.S.

In June, 1937, Mr. H. E. Wimperis, President 1936-38, sailed for Australia to advise the Australian Government on research and other aviation problems. Mr. Wimperis, though it was known he would be away for the greater part of the time, was unanimously asked by the Council to serve a second year of office and to convey, as President of the Society, the Council's cordial greetings and good wishes to the branches in Canada and Australia and such members of the Society whom he may meet.

Mr. Wimperis, while in Canada, had an opportunity of meeting members of the Ottawa Branch, where he had an enthusiastic welcome. A number of matters affecting the future of the branch were usefully discussed, and since Mr. Wimperis's return some of the suggestions made have been put into practice.

While in Canada the President represented the Society at the Semi-Centennial meeting of the Engineering Institute and conveyed the cordial greetings of the Society to the Congress and presented an illuminated address. He had the opportunity of meeting the chief figures in the aeronautical world in Canada and addressing the Congress on the problems of trans-Atlantic flying.

In Australia the President lectured before the branch and made use of the opportunity to discuss how the parent Society could help. A deputation from the branch welcomed the President on board ship on his arrival in Australia and the Royal Australian Air Force sent out a flight of machines to fly over the ship to greet the President.

The following cable was received from the President:—

> "The President of Society and Australasian Branch assembled here in Sydney send their cordial greetings to Council and members in Britain and express unbounded belief in the wide-world influence for good of the Society in whose work they are proud to take their part."

To which the following reply was sent:—

> "Council and members reciprocate heartily the cordial greetings of the President of the Society and Australasian Branch and look forward confidently to the Branch becoming of increasing and vital importance in Australian aviation."

While in Australia the President was given the high honour of Honorary Degree of Doctor of Engineering of the Melbourne University.

The Council wish to place on record their grateful thanks for the very great help the President gave to the branches on his visit, and for the added prestige he brought to the Society while in Canada and Australia.

COUNCIL DINNER TO MR. WIMPERIS, C.B., C.B.E., M.A., M.I.E.E., F.R.Ae.S., AT THE ATHENÆUM ON WEDNESDAY, OCTOBER 26TH.

The Council entertained Mr. Wimperis on his return to this country when he gave them an account of his visit.

The following attended the dinner:—

Mr. R. Blackburn, O.B.E., A.M.Inst.C.E., M.I.M.E., F.R.Ae.S.
Mr. Griffith Brewer, Hon. F.R.Ae.S.
Major J. S. Buchanan, F.R.Ae.S.
Major G. P. Bulman, O.B.E., B.Sc., M.I.A.S., F.R.Ae.S.
Mr. S. Camm, F.R.Ae.S.
Mr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc., F.R.Ae.S.
Mr. W. C. Devereux, F.R.Ae.S.
Mr. A. H. R. Fedden, M.B.E., M.I.A.E., M.S.A.E., F.R.Ae.S.
Mr. A. Gouge, B.Sc., F.R.Ae.S.
Mr. A. H. Hall, C.B., C.B.E., M.Inst.C.E., M.I.M.E., F.R.Ae.S.

Professor G. T. R. Hill, M.C., M.Sc., F.R.Ae.S.
Mr. J. E. Hodgson, Hon. F.R.Ae.S. (Honorary Librarian).
Major D. H. Kennedy, O.B.E., F.R.Ae.S. (Honorary Treasurer).
Lieut.-Col. W. Lockwood Marsh, O.B.E., F.R.Ae.S.
Mr. F. Handley Page, C.B.E., F.R.Ae.S.
Professor A. J. Sutton Pippard, M.B.E., D.Sc., M.Inst.C.E., F.R.Ae.S.
Captain J. Laurence Pritchard, Hon. F.R.Ae.S., A.F.I.Ae.S. (Secretary).
Mr. D. R. Pye, C.B., F.R.S., M.A., Sc.D., M.I.Mech.E., F.R.Ae.S.
Mr. E. F. Relf, F.R.S., A.R.C.Sc., F.R.Ae.S.
Mr. A. N. D. Smith, F.C.A. (Honorary Accountant).
Mr. H. E. Wimperis, C.B., C.B.E., M.A., M.I.E.E., F.R.Ae.S.
Mr. Lawrence A. Wingfield, M.C., D.F.C., A.R.Ae.S.I. (Solicitor).

ELECTION OF PRESIDENT.

Mr. A. H. R. Fedden, M.B.E., D.Sc., M.I.A.E., M.I.Mech.E., M.S.A.E., F.R.Ae.S., Vice-President, was elected President of the Society for the year 1938-1939 at the Council Meeting in May, 1938.

VICE-PRESIDENTS.

The following Vice-Presidents for October, 1938—September, 1939, were elected at the Council Meeting in May, 1938:—

Mr. Griffith Brewer, Honorary Fellow.
Mr. D. R. Pye, C.B., F.R.S., M.A., Sc.D., M.I.Mech.E., F.R.Ae.S.

HONOURS.

The following Honours were conferred on members of the Society during the year under review:—

*Viscounty*—Lord Weir of Eastwood (Fellow).

*C.B.E.*—Professor B. Melvill Jones (Fellow).

*O.B.E.*—Squadron Leader K. L. Boswell (Associate Fellow).

*Chevalier of the Legion of Honour*—Captain Leonard Plugge (Fellow).

Mr. A. H. R. Fedden, M.B.E., M.I.A.E., M.S.A.E., Fellow—a Degree of Engineering from Bristol University.

Flight Lieut. W. F. Pharazyn, Associate Fellow—First Prize in the Gordon Shephard Memorial Prize Essay Awards.

*Guggenheim Gold Medal.*—The Guggenheim Gold Medal for 1938 was awarded to Mr. A. H. R. Fedden, M.B.E., M.I.A.E., M.I.Mech.E., F.R.Ae.S., for his work on the development of aero engines, and particularly the sleeve valve engine.

WILBUR WRIGHT MEMORIAL LECTURE.

The 26th Wilbur Wright Memorial Lecture was delivered by Dr. H. J. Gough, M.B.E., M.I.Mech.E., F.R.S., on "Materials of Aircraft Construction." A full report was given in the November, 1938, Journal.

AWARDS.

A full list of awards made early in 1938 was published in the Report of the Council for 1938, in the Journal for March, 1938 (page 274).

LECTURE PROGRAMME.

Jan. 13th.—Squadron Leader R. S. Blucke, A.F.C., "The Practical Use of Radio as a Direct Aid to the Landing Approach in Conditions of Low Visibility."

Jan. 27th.—Discussion on "High Wing Loading and the Three-Wheeled Undercarriage."

Feb. 3rd.—E. F. Relf, A.R.C.Sc., F.R.S., F.R.Ae.S., "Recent Research on the Improvement of the Aerodynamic Characteristics of Aircraft."

March 3rd.—Dr.-Ing. Wilhelm Pleines, "Riveting Methods and Rivet Equipments Used in German Light Metal Aeroplane Construction."

April 7th.—Dr. E. G. Richardson, B.A., Ph.D., D.Sc., "The Manipulation of the Boundary Layer."

April 21st.—John E. Younger, Ph.D., A.F.I.Ae.S., "Engineering Aspects of Commercial High Altitude Flying (with Particular Reference to Recent Development in the United States)."

May 26th.—Dr. H. J. Gough, M.B.E., D.Sc., M.I.Mech.E., F.R.S., "Materials of Aircraft Construction," 26th Wilbur Wright Memorial Lecture.

Oct. 20th.—Monsieur R. le Coeuvre, "The Use of Light Alloys in Aircraft Construction."

Nov. 3rd.—F. Entwistle, B.Sc., "The Meteorological Problem of the North Atlantic."

Nov. 9th.—T. P. Wright, F.I.Ae.S., F.R.Ae.S., "American Methods of Aircraft Production."

Nov. 17th.—Dr. F. Seewald, "The Work of the D.V.L."

Dec. 1st.—Professor G. T. R. Hill, M.C., M.Sc., F.R.Ae.S., "Flying Controls."

Dec. 15th.—Herr A. Lippisch, A.F.R.Ae.S., "Some Results from the Deutsche Forschungsanstalt für Segelflug Smoke Tunnel."

BRANCH LECTURES.

*Bristol Branch.*

Jan. 18th.—"High Altitude Flight," by Flight Lieut. M. J. Adam.

March 1st.—Lecture by Dr. T. Swinden on "Steel Development as Related to the Aero Industry."

*Coventry Branch.*

Jan. 20th.—"The Installation of Aero Engines," by Dr. G. P. Douglas, M.C., A.F.R.Ae.S.

Feb. 17th.—Lecture by Major F. M. Green, O.B.E., M.Inst.C.E., F.R.Ae.S., on "Aircraft Motive Power."

March 17th.—Lecture by Captain J. L. Pritchard, Hon. F.R.Ae.S., on "The Ruts of Aviation."

April 21st.—Lecture by Mr. E. F. Relf, F.R.S., A.R.C.Sc., F.R.Ae.S., on "The Compressed Air Wind Tunnel and its Results."

Oct. 20th.—A Lecture on "Inspection," by a member of the A.I.D. Staff.

Dec. 15th.—Lecture by Mr. E. W. Knott, M.I.A.E., M.S.A.E., on "Carburation as Applied to Modern Aircraft Engines."

*Isle of Wight Branch.*

Jan. 11th.—"Aircraft Inspection Methods," by Mr. R. H. Longe.

Jan. 25th.—"Bird Flight in Relation to the Aeroplane," by Captain J. Laurence Pritchard, Hon. F.R.Ae.S., A.F.I.Ae.S.

Feb. 8th.—"Tank Testing of Flying Boat Hulls with its Application to Full Scale," by Mr. L. P. Coombes, D.F.C., B.Sc., A.C.G.I., A.F.R.Ae.S.

Feb. 22nd.—Lecture by Captain Norman Macmillan, M.C., A.F.C., F.R.S.A., A.F.R.Ae.S., on "Flying and Handling of Seaplanes and Flying Boats."

March 8th.—Lecture by Dr. G. P. Douglas, M.C., A.F.R.Ae.S., on "Cowling and Cooling and Air-Cooled Aero Engines."

March 22nd.—Lecture by Captain P. W. Lynche-Blosse on "Air Route and Aerodrome Control."

April 12th.—Lecture by Mr. L. Leech, on "Tool Design and Manufacture."

Nov. 8th.—Lecture by Squadron Leader H. J. Saker on "Aircraft Instruments."

Nov. 22nd.—Lecture by Dr. H. Roxbee Cox, F.R.Ae.S., on "The Future Development of Aircraft Construction."

Dec. 6th.—Lecture by Captain F. T. Courtney on "Flight Testing."

*Manchester Branch.*

Jan. 13th.—"The Future of Light Alloys in Aircraft Construction," by Mr. W. C. Devereux, F.R.Ae.S.

Feb. 10th.—"Wing Flaps and Tapered Wings," by Mr. H. B. Irving, B.Sc., F.R.Ae.S.

March 10th.—Lecture by Dr. R. C. Sutcliffe, of the Meteorological Office, on "Clouds and their Formation, Structure, and Associated Flying Conditions."

April 7th.—Lecture by Mr. H. B. Gillmore on "Variable Pitch Airscrews."

April 28th.—Lecture by Squadron Leader G. M. Buxton, R.A.F., on "Development of Sailplanes."

*Medway (Rochester) Branch.*

Oct. 3rd.—Lecture by Mr. A. Gouge, B.Sc., F.R.Ae.S., on "The Growth of Aviation."

Nov. 7th.—Lecture by Mr. J. Grierson, on "An Arctic Air Route Flight."

Dec. 5th.—Lecture by Mr. J. G. Hopcraft, A.M.I.Ae.E., on "Steel and its Manufacture."

*Portsmouth Branch.*

Jan. 20th.—"Aircraft of the Future," by Mr. A. Hessell Tiltman, F.R.Ae.S.

Feb. 10th.—"Cowling and Cooling of Radial Engines," by Dr. G. P. Douglas, M.C., A.F.R.Ae.S.

Feb. 24th.—Lecture by Major H. Hemming, A.F.C., F.R.G.S., F.R.Ae.S., on "Air Survey."

March 10th.—Lecture by Sergeant Barnes, on "Air Raid Precautions in Portsmouth."

March 24th.—Lecture by Sir Alan J. Cobham, Hon. F.R.Ae.S., on "Problems and Possibilities of Refuelling in the Air."

Nov. 3rd.—Lecture by Mr. Kirke W. Connor on "Honing of Machined Parts for Aircraft."

Nov. 10th.—Lecture by Mr. A. F. Houlberg, A.F.R.Ae.S., on "Production Methods in the Motor Car Industry."

Nov. 24th.—Lecture by Mr. R. H. Bundy on "Wood from the Seed Upwards."

Dec. 8th.—Lecture by Mr. G. H. Dowty, F.R.Ae.S., M.I.Ae.E., on "Retractable Undercarriages."

Dec. 15th.—Discussional Evening. Three Short Lectures by Airspeed personnel.

*Southampton Branch.*

Jan. 5th.—" Aircraft Production," by Mr. H. J. Pollard, A.F.R.Ae.S.

March 2nd.—Lecture by Flight Lieut. H. F. Jenkins, on " De-Icing."

April 6th.—Lecture by F. Entwistle, B.Sc., on " Recent Developments in Meteorology."

Nov. 2nd.—Lecture by Mr. G. H. Dowty, F.R.Ae.S., M.I.Ae.E., on " Retractable Undercarriages."

*Weybridge Branch.*

Jan. 5th.—" Experimental Methods of Structural Analysis," by Professor A. J. Sutton Pippard, M.B.E., D.Sc., F.R.Ae.S. Chairman: Mr. B. N. Wallis.

Jan. 19th.—" The Use of Multi-Tool Lathes, Gear Shapers and Broaching Machines," by a Member of the Staff of Drummond Brothers, Limited.

Feb. 2nd.—" The Heat Treatment of Duralumin," by Major P. L. Teed, M.Inst.M.M.

Feb. 16th.—Lecture by Mr. D. A. Kitching, A.M.I.E.E., on " The Electrical Installation at Vickers' Works." Chairman: Mr. Fitzroy Woods. A.M.I.E.E.

March 2nd.—Lecture by Mr. E. F. Relf, A.R.C.Sc., F.R.S., F.R.Ae.S., on " Aerodynamic Research at the National Physical Laboratory." Chairman: Mr. D. L. Ellis, B.Sc., A.R.T.C., A.F.R.Ae.S.

April 6th.—Lecture by Mr. I. J. Gerard, M.Sc., A.M.Inst.C.E., A.F.R.Ae.S., on " Stressed Skin Construction."

Oct. 5th.—Presidential Address, Mr. B. N. Wallis, B.Sc., M.Inst.C.E., F.R.Ae.S. Mr. R. K. Pierson, M.B.E., B.Sc., A.M.Inst.C.E., F.R.Ae.S., in the chair.

Oct. 26th.—Lecture by Mr. John Hopcraft, A.M.I.Ae.E., on " Manufacture of Stainless Steel." Major P. L. Teed, M.Inst.M.M., in the chair.

Nov. 14th.—Lecture by Mr. H. E. Serby, B.A., on " Full-Scale Experiments on Aeroplanes."

Nov. 30th.—Lecture by Captain J. A. Sinclair on " Airships."

Dec. 14th.—Lecture by Mr. S. Veale on " The History of Aviation."

*Yeovil Branch (Westland Aircraft Society).*

Jan. 13th.—" Aero Engine Design," by a Representative of Messrs. de Havilland Aircraft Company, Limited.

Feb. 10th.—Lecture by Mr. L. A. Sweny, on " Radio for Aircraft Services."

Feb. 24th.—Lecture by Mr. W. O. Manning, F.R.Ae.S., on " Flying with the Pioneers at Brooklands."

Nov. 17th.—Lecture by Mr. R. Worsdale on " Extrusions."

Dec. 15th.—Lecture by Mr. W. E. W. Petter, A.F.R.Ae.S., " The Paris Aero Show."

OTHER LECTURES.

Feb. 4th.—Lecture before the Engineering Society, University College, by Captain J. Laurence Pritchard, Hon. F.R.Ae.S., on " The Queer Side of Flying."

Feb. 11th.—Lecture before Rutherford College, Newcastle-upon-Tyne, by Mr. J. Bell, A.R.Ae.S.I., on " A Trip into the Stratosphere."

Feb. 15th.—Lecture before the Grantham Engineering Society, Grantham, by Captain J. Laurence Pritchard, Hon. F.R.Ae.S., on " Flying in the Stratosphere."

Oct. 19th.—Lecture before the Birmingham Junior Chamber of Commerce by Captain J. Laurence Pritchard, Hon. F.R.Ae.S., on "Commercial Atlantic Flying."

Nov. 1st.—Lecture before the Engineering Society, Queen Mary College, Mile End Road, E.1, by Captain J. Laurence Pritchard, Hon. F.R.Ae.S., on "Bird Flight."

Nov. 10th.—Lecture before the Working Men's College, Crowndale Road, N.W.1, by Captain J. Laurence Pritchard, Hon. F.R.Ae.S., on "Military Aviation."

GRADUATES' AND STUDENTS' SECTION.

The following summarises the activities of the Students' Section for 1938:—

*Officers and Committee for* 1938.

*Chairman*: J. C. Hardman.

*Vice-Chairman*: D. R. Sherwin.

*Hon. Secretary*: R. B. Wilkinson.

*Committee*: L. G. Whitehead, H. Udall, F. T. Meacock, A. F. Walsh, J. C. Hardman, H. E. J. Rochefort, D. A. J. Harben.

Jan. 18th.—"Turbulence and Skin Friction," Mr. A. A. Hall, B.A. Chairman: Mr. H. B. Squire, M.A., A.F.R.Ae.S.

Feb. 1st.—"Notes on Aero Engine Research," Mr. P. H. Rayner, B.Sc. Chairman: Mr. D. R. Pye, C.B., F.R.S., M.A., F.R.Ae.S.

Feb. 15th.—"Control Surface Design," Mr. A. F. Walsh, B.Sc. Chairman: Mr. W. R. Andrews, A.F.R.Ae.S.

March 1st.—"Transport Aviation in Canada." Mr. H. M. Gallay, B.Sc., M.I.Ae.S. Chairman: Mr. C. G. Grey.

March 22nd.—"Theory and Application of Stressed Skin Construction," Mr. H. E. J. Rochefort, Wh. Sch., A.C.G.I., D.I.C. Chairman: Mr. H. Roxbee Cox, Ph.D., D.I.C., F.R.Ae.S.

March 29th.—Lecture by Mr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc., F.R.Ae.S., on "Large Aeroplanes." Chairman: Major C. J. Stewart, O.B.E., M.I.M.E., M.I.A.E., F.R.Ae.S.

April 26th.—Lecture by Mr. L. R. E. Castlemaine, on "Atlantic Air Routes." Chairman: Mr. D. L. Hollis Williams, B.Sc., F.R.Ae.S.

Sept. 20th.—Annual General Meeting.

Oct. 25th.—Lecture on "Wings and Control Surfaces," by Mr. D. L. Ellis, B.Sc., A.R.T.C., A.F.R.Ae.S., at 7.0 p.m. Dr. H. Roxbee Cox, D.I.C., F.R.Ae.S., in the chair.

Nov. 4th.—Informal Supper at the Royal Aero Club, W.1.

Nov. 8th.—Lecture on "Design, Construction and Efficiency of Wind Tunnels," by Mr. E. A. Wright (Student), at 7.0 p.m. Mr. E. Ower, Fellow, in the chair.

Nov. 22nd.—Lecture on "Meteorology," by Mr. F. Entwistle, B.Sc., at 7 p.m. Mr. P. G. Masefield, B.A., in the chair.

Dec. 8th.—Joint Lecture with the Students' Section of the Institution of Automobile Engineers and other bodies at 12, Hobart Place, S.W.1, at 7 p.m. Lecture on "Carburation and Induction in Aircraft Engines," by Mr. K. C. Hunt, of the Anglo-American Oil Company, Limited.

Dec. 20th.—Lecture on "The Air Mail Scheme," by Mr. Gibson Pattison, F.S.S. (Student), at 7 p.m.

The following Visits to Works were made:—

Jan. 22nd.—Visit to the Fairey Aviation Works, Hayes, Middlesex.

Feb. 19th.—Visit to Marconi's Aircraft Establishments at Hackbridge and Croydon.

March 19th.—Visit to the National Physical Laboratory.

April 9th.—Visit to Heston Airport, Heston, Middlesex.

May 19th.—Visit to the Bristol Aeroplane Company's Works, Filton, Bristol.
Oct. 22nd.—Visit to Royal Air Force Station at North Weald, Epping, Essex.
Nov. 19th.—Visit to Imperial Airways, Limited, at Croydon Airport.
Dec. 3rd.—Visit to Phillips and Powis, Limited, Reading.

ELLIOTT MEMORIAL PRIZE.

The Elliott Memorial Prize was awarded to Leading Aircraft Apprentice P. N. Sherwood and Leading Aircraftsman G. Hampton.

ACKNOWLEDGMENTS.

The Council gratefully acknowledges the following:—

Back numbers of the Journal and other Society publications from Mr. R. Howard-Flanders (Associate Fellow); Mr. R. Glyn Jones (Associate Member); Captain Norman McMillan, M.C., A.F.C., F.R.S.A., A.F.R.Ae.S.; Mr. F. P. Walsh; Mr. S. Slaughter (Associate); Miss L. Chitty (Fellow); Mr. M. H. Volk (Fellow); Mrs. Hynes; and Major B. W. Shilson (Fellow).

Slides, films and photographs from Mr. Gregory and M. Emile Cohn.

Library books, publications and periodicals from Mr. J. E. Beckett (Founder Member), Lord Baden-Powell, Professor Riabouchinsky, and Mr. F. P. Walsh (Associate Fellow); Major Henri Jullerot; Mr. A. P. Targett-Adams (Companion), Mr. W. O. Manning (Fellow), Society of British Aircraft Constructors, Mr. A. R. Weyl (Associate Fellow), Mr. Clarence Winchester (Associate), Mr. T. B. Ringwood (Associate Member).

BRANCHES.

During the year two new Branches were formed, one at Rochester and one in Belfast and both branches have made a good start in lecture programmes and membership. There are now fifteen branches of the Society and the Council wish to thank all those concerned with the progress made. The Chairmen, Committee and Honorary Secretaries are to be congratulated on the results of their efforts.

The following is a list of Branches:—

*Australian Branch.*
Chairman: T. D. J. Leech, B.Sc., B.E., M.I.Ae.E.
Hon. Secretary: Philip H. Vyner, A.M.I.Ae.E.
Address: Science House, Gloucester and Essex Streets, Sydney, Australia.

*Belfast Branch.*
Chairman: J. H. Lower, Esq., A.M.I.N.A., A.F.R.Ae.S.
Hon. Secretary: W. H. Hambrook, Esq., A.F.R.Ae.S.
Address: Short and Harland, Limited, Queen's Island, Belfast.

*Bristol Branch.*
President: H. J. Thomas, Esq.
Chairman: N. Rowbotham, Esq., A.F.R.Ae.S.
Hon. Secretary: H. Yendall, Esq.
Address: 20, The Crescent, Henleaze, Bristol.

*Cambridge University Engineering and Aeronautical Society* (affiliated to the Royal Aeronautical Society).
President: R. H. Angus, Esq., M.A.
Aeronautical Section—President: J. J. Holden, Esq.
Secretary: C. M. Miller, Esq.
Address: Corpus Christi.

*Coventry Branch.*
Chairman: Air Marshal Sir John Higgins, J.P., K.C.B., D.S.O., A.F.C., F.R.Ae.S.
Hon. Secretary: S. A. Powell-Jones, Esq.
Address: Sir W. G. Armstrong-Whitworth Aircraft Limited, Coventry.

*Gloucester and Cheltenham Branch.*

President: T. O. M. Sopwith, Esq., C.B.E., F.R.Ae.S.
Chairman: W. G. Carter, Esq., M.B.E., F.R.Ae.S.
Hon. Secretary: F. B. Ford, Esq., A.F.R.Ae.S.
Address: St. Margaret, Brockworth, Nr. Gloucester.

*Hull and Leeds Branch.*

Chairman: Major F. A. Bumpus, B.Sc., F.R.Ae.S.
Hon. Secretary: W. D. Murray, Esq., A.F.R.Ae.S.
Address: Blackburn Aircraft, Limited, Brough, E. Yorks.

*Isle of Wight Branch.*

President: Sqdn. Ldr. C. J. W. Darwin, D.S.O., R.A.F. (Retd.).
Chairman: H. Knowler, Esq., A.M.Inst.C.E., F.R.Ae.S.
Hon. Secretary: M. J. Brennan, Esq., B.Sc., A.F.R.Ae.S.
Address: "Harclare," Wyatts Lane, Cowes, I.O.W.

*Manchester Branch.*

Chairman: R. Chadwick, Esq., F.R.Ae.S.
Hon. Secretary: J. A. E. Waterfall, Esq.
Address: 56, Manor Avenue, Ashton-on-Mersey, Cheshire.

*Medway Branch.*

President: H. O. Short, Esq., F.R.Ae.S.
Chairman: A. Gouge, Esq., B.Sc., F.R.Ae.S.
Hon. Secretary: J. W. Loader, Esq., B.Sc., A.F.R.Ae.S.
Address: 174, City Way, Rochester, Kent.

*Montreal Branch.*

Address of Hon. Secretary: Engineering Institute of Canada, 2050, Mansfield Street, Montreal, Canada.

*Ottawa Branch.*

President: Sqdn. Ldr. G. E. Wait, B.A.Sc., D.I.C., A.F.R.Ae.S.
Hon. Secretary: M. S. Kuhring, Esq., A.R.Ae.S.I.
Address: National Research Council, Aeronautical Laboratory, Ottawa, Canada.

*Portsmouth Branch.*

President: A. H. Tiltman, Esq., B.Sc., F.R.Ae.S.
Chairman: E. C. Green, Esq.
Hon. Secretary: J. F. Foss, Esq.
Address: c/o Airspeed (1934) Limited, The Airport, Portsmouth, Hants.

*Southampton Branch.*

Chairman: Sqdn.-Ldr. H. F. Jenkins, A.F.C.
Hon. Secretary: T. Tanner, Esq., A.C.G.I., D.I.C., A.F.R.Ae.S.
Address: University College, Southampton, Hants.

*Weybridge Branch.*

President: B. N. Wallis, Esq., B.Sc., M.Inst.C.E., F.R.Ae.S.
Chairman: F. Holliday, Esq., B.Sc., F.R.S., A.R.Ae.S.I.
Hon Secretary: D. L. Ellis, Esq., B.Sc., A.R.T.C., A.F.R.Ae.S.
Address: c/o Vickers (Aviation), Limited, Weybridge, Surrey.

*Yeovil Branch.*

President: Captain P. D. Acland.
Hon. Secretary: T. H. Burleigh, Esq., R.A.F.O., A.R.Ae.S.I.
Address: Westland Aircraft, Limited, Yeovil, Somerset.

SOCIETY OF BRITISH AIRCRAFT CONSTRUCTORS' SCHOLARSHIPS.

The Scholarships' Selection Committee of the Society of British Aircraft Constructors and the Royal Aeronautical Society made awards of Society of British Aircraft Constructors' Scholarships to the following:—

Eric Richard Lovelace Crook.
John Reginald Gardiner.
John Gareth Frank Lang.
Dennis Levitt.
George Edwin Harold Vickers.

ASSOCIATE FELLOWSHIP AND ASSOCIATE MEMBERSHIP EXAMINATIONS.

The following candidates were successful in the December, 1937, examinations held in London:—

ASSOCIATE FELLOWSHIP.

| | |
|---|---|
| D. A. Clifton-Mogg ... | Design (Aircraft). |
| K. R. Davies ... ... | Applied Mathematics.<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines) (First Place). |
| W. T. Fisher ... ... | Applied Mathematics.<br>Aerodynamics.<br>Design (Aircraft). |
| D. J. How ... ... | Pure Mathematics (First Place).<br>Aerodynamics.<br>Air Transport. |
| D. M. Jameson ... ... | Pure Mathematics.<br>Strength of Aeronautical Materials and Structures.<br>Aerodynamics. |
| R. M. Leach ... ... | Applied Mathematics.<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| J. L. Longden ... ... | Applied Mathematics.<br>Theory of Internal Combustion Engines (First Place).<br>Design (Aero Engines). |
| C. D. N. Longley ... | Applied Mathematics (First Place).<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| W. S. Lucke ... ... | Theory of Internal Combustion Engines. |
| J. Macaulay-Service ... | Applied Mathematics.<br>Aerodynamics.<br>Design (Aircraft). |
| J. P. A. Martindale ... | Pure Mathematics. |
| S. C. Moitra ... ... | Aircraft Materials. |
| L. E. Moore ... ... | Aircraft Materials (First Place). |
| E. J. Niedermayer ... | Applied Mathematics.<br>Strength of Aeronautical Materials and Structures.<br>Design (Aircraft). |
| C. H. Nundy ... ... | Applied Mathematics. |
| J. F. M. Oram ... ... | Applied Mathematics.<br>Theory of Machines. |
| M. H. Paranjpye ... | Applied Mathematics.<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines). |

| | |
|---|---|
| D. B. Peter ... ... | Pure Mathematics.<br>Aerodynamics.<br>Design (Aircraft). |
| F. R. J. Spearman ... | Applied Mathematics.<br>Aerodynamics (First Place).<br>Design (Aircraft). |
| K. J. Spooner ... ... | Applied Mathematics.<br>Theory of Internal Combustion Engines. |
| G. I. Wain ... ... | Applied Mathematics. |
| W. A. C. Weetman ... | Applied Mathematics. |
| A. P. West ... ... | Strength of Aeronautical Materials and Structures. |
| R. B. Wilkinson ... | Applied Mathematics.<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| J. G. Willis ... ... | Applied Mathematics.<br>Strength of Aeronautical Materials and Structures.<br>Design (Aircraft) (First Place). |
| H. G. Winton ... ... | Aerodynamics. |

ASSOCIATE MEMBERSHIP.

| | |
|---|---|
| R. E. Cunningham ... | Theory of Internal Combustion Engines.<br>Design (Aero Engines) (First Place). |
| K. P. Dunckley ... .. | Applied Mathematics.<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| A. K. Ellison ... ... | Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| R. S. Emerson ... ... | Applied Mathematics.<br>Theory of Internal Combustion Engines. |
| A. St. G. Harris ... | Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| N. W. Y. Hatherly ... | Applied Mathematics.<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| B. R. Hutchinson ... | Applied Mathematics.<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| R. L. Lake ... ... | Applied Mathematics.<br>Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| M. E. Mattinson ... | Theory of Internal Combustion Engines. |
| R. C. Pike ... ... | Strength of Aeronautical Materials and Structures.<br>Design (Aircraft). |
| I. C. Randrup ... ... | Design (Aero Engines). |
| N. W. Ridgway ... ... | Design (Aero Engines). |
| A. R. Sarup ... ... | Aircraft Materials. |
| W. E. Wakely ... ... | Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| D. L. Wallis ... ... | Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| L. S. Wigdortchik ... | Applied Mathematics (First Place).<br>Theory of Internal Combustion Engines (First Place).<br>Design (Aero Engines). |

The following is a list of those who passed in the December, 1938, examinations, and the subjects in which they passed:—

ASSOCIATE FELLOWSHIP.

| | |
|---|---|
| P. R. Allison ... ... | Theory of Internal Combustion Engines<br>Applied Mathematics.<br>Design (Aero Engines). |
| F. N. B. Bennett ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| J. R. Batty ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| A. E. Draper ... ... | Strength of Aeronautical Materials and Structures. |
| F. A. Firth ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| R. H. D. Forbes ... ... | Strength of Aeronautical Materials and Structures.<br>Applied Mathematics.<br>Aerodynamics (First Place). |
| T. D. Griffin ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| D. Hill ... ... ... | Strength of Aeronautical Materials and Structures (First Place).<br>Applied Mathematics.<br>Design (Aircraft). |
| O. L. Hyde ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| H. M. Kendall ... ... | Design (Aero Engines). |
| P. G. G. Knight ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| N. A. Simpson ... ... | Theory of Internal Combustion Engines<br>Applied Mathematics.<br>Design (Aero Engines). |
| R. T. Wall ... ... | Theory of Internal Combustion Engines (First Place).<br>Applied Mathematics (First Place).<br>Design (Aero Engines) (First Place). |
| C. H. Wang ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Aerodynamics. |

ASSOCIATE MEMBERSHIP.

| | |
|---|---|
| D. R. F. Barron ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| D. Diamond ... ... | Pure Mathematics.<br>Design (Aircraft). |
| W. H. Edwards ... ... | Theory of Internal Combustion Engines (First Place).<br>Applied Mathematics (First Place).<br>Design (Aero Engines) (First Place). |
| R. S. Emerson ... ... | Design (Aero Engines). |

| | |
|---|---|
| S. G. Heath ... ... | Applied Mathematics. |
| H. B. H. Judd ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| H. M. D. Magill ... ... | Applied Mathematics.<br>Design (Aero Engines). |
| F. C. Nottingham ... | Aircraft Materials. |
| B. H. Pegge ... ... | Applied Mathematics.<br>Design (Aircraft). |
| R. F. Rowley ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |
| R. Stallebrass ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Design (Aero Engines). |

The following candidates were successful at the examinations held in May, 1938:—

ASSOCIATE FELLOWSHIP.

| | |
|---|---|
| J. B. Bayas ... ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Aircraft Materials. |
| J. P. Booth ... ... ... | Strength of Aeronautical Materials and Structures.<br>Aerodynamics (1st place). |
| J. A. Channer ... ... | Theory of Internal Combustion Engines. |
| H. J. Crampton ... ... | Strength of Aeronautical Materials and Structures.<br>Applied Mathematics.<br>Aerodynamics. |
| L. Crowther ... ... ... | Strength of Aeronautical Materials and Structures (1st place).<br>Applied Mathematics (1st place).<br>Design (Aircraft) (1st place, tied). |
| D. C. Jenkins ... ... | Pure Mathematics (1st place). |
| H. M. Kendall ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics. |
| H. G. Litchfield ... ... | Applied Mathematics.<br>Design (Aircraft). |
| W. S. Lucke ... ... | Design (Aero Engines) (1st place). |
| M. McInerney ... ... | Pure Mathematics.<br>Aerodynamics. |
| C. H. Nundy ... ... | Design (Aircraft). |
| T. B. O'Reilly ... ... | Applied Mathematics. |
| I. H. Rees ... ... ... | Aerodynamics.<br>Design (Aircraft). |
| P. P. Robinson ... ... | Applied Mathematics. |
| M. S. Spickernell ... ... | Pure Mathematics. |
| K. J. Spooner ... ... | Design (Aero Engines). |
| H. G. Winton ... ... | Design (Aircraft) (1st place, tied). |
| R. T. Wood ... ... .. | Applied Mathematics. |

ASSOCIATE MEMBERSHIP.

| | |
|---|---|
| W. B. Coles ... ... ... | Pure Mathematics.<br>Aerodynamics. |
| R. E. Cunningham ... ... | Pure Mathematics. |
| A. St. G. Harris ... ... | Applied Mathematics. |

| | |
|---|---|
| F. C. Nottingham ... ... | Theory of Internal Combustion Engines.<br>Design (Aero Engines). |
| F. L. Payne ... ... ... | Theory of Internal Combustion Engines.<br>Applied Mathematics.<br>Theory of Machines. |
| D. H. Wilson ... ... | Strength of Aeronautical Materials and Structures.<br>Pure Mathematics.<br>Design (Aircraft). |

MAJOR BADEN-POWELL MEMORIAL PRIZE.

The Major Baden-Powell Memorial Prize was awarded to Mr. R. T. Wall, who was considered the best Student by the Examiners at the December Examinations, and to Mr. L. Crowther, who was considered the best Student in the May Examinations.

ELECTION OF MEMBERS.

The following members have been elected since the last Report:—

On December 14th, 1937:—

*Fellow.*—William Helmore (from Associate Fellow).

*Associate Fellows.*—P. Adorjan (from Companion), J. D. Akerman, F. D. Crowe, C. W. Hayes, R. J. H. Hudson, C. N. Jaques, H. F. King, S. M. Parker, G. N. Patterson, F. H. Pollicutt, S. A. W. Thompson (from Student).

*Associate Members.*—T. Pountney (from Student), M. H. Swift, N. L. Walker (from Associate).

*Associates.*—Noel Britton (from Student), J. Emmett, J. Hartshorne, Miss S. E. McGuffie (from Student), E. L. Shankland, J. B. Wilson, Clarence Winchester.

*Graduates.*—F. A. Sprankling, J. B. Thompson.

*Companion.*—H. Chinery.

*Students.*—R. H. Anderson, C. A. C. Chetham, C. R. Dunn, R. H. D. Forbes, J. F. Holmes-Smith, J. Love, J. P. McKenzie, J. McLennan, D. D. Marples, E. C. W. Pearce, J. P. Renateau, G. I. Robinson.

On January 11th, 1938:—

*Fellow.*—David Leonard Hollis Williams (from Associate Fellow).

*Associate Fellows.*—Harold Balint Boszormenyi, Newsome Henry Clough, Colin Havard Hunter, Norton Bartlett Moore, Charles Lewis Wright (from Student).

*Associate Members.*—Calvert Armstrong (from Student), Athelstan Eric Williams.

*Associates.*—Thomas Haydon Burleigh, Philip Murray Scott.

*Graduates.*—Douglas Favel Horne, Edgar W. Reissner, John Arthur Charles Williams (from Student).

*Students.*—Charles Dudley Anderson, Frederick James Bigg, Robert Thornley Bowring, Clifford Ernest Cocklan, Benjamin Elliott, William Thoby Fisher, Ian Malcolm Hamer, Maurice Arthur Hirst, William Hayes Jackson, Cyril Michael Light, James Armstrong Lundy, John L. Orr, George Kenneth More, Frederick Victor Rehill, Miss Brenda M. Rimmer, John Carl Siltanen, George Ingram Sprent, Denis Edward Thackeray.

*Companions.*—John Reginald Bryans, Miss Rosamund King Everard.

On February 8th, 1938:—

*Fellows.*—Walter Brierley (from Associate Fellow), Barnes Neville Wallis.

*Associate Fellows.*—Edmund Roy Cooper (from Student), Robert William Corbitt, Herbert Jeffree, Maurice Glyn Lloyd-Jones, Robert Pringle, Harold Zettersten (from Companion).

*Associate Member.*—Erich Carl Albert Backhaus (from Associate), John Burt Flynn (from Associate, Australian Branch).

*Associates.*—Willian Roy Baird (from Associate Fellow), Percival Lester Barling, A. M. de Hauteville Bell, Ronald Ogilvy Maurice Graham (from Student), Dinabandhu Guha.

*Graduates.*—Henry Aldin Craw (from Student), Peter Alan Lantsbery Grear (from Student), Geoffrey Patrick Hebden (from Student), David Mellor Jameson, Arthur Oliver Mattocks (from Student), George Wishart Nicholas, Arthur Drummond Williams Pimm (from Companion).

*Students.*—Hubert John Allwright, David Charles Appleyard, D. S. Bancroft, Robert Pierssene Battey, Charles Kenneth Bonner, Alan Bremner Coates, Mirea M. Conea, Jere Tiffin Farrah, Frank John French, Henry James Suffolk Hall, Alfred Holmes Hammond, Yushan Huang, Peter George Gradwick Knight, Hubert Desmond Leigh, Herbert Edward Le Sueur, Joseph Levine, John Joseph Lindsay, Ernest Henry Nason, George Edward Otter, Angus Rayfield Pitt, William Rieter, Claude Whittard Slatter, Ian Maxwell Strachan, Leo A. Weiss, George Brownlee Young.

*Companion.*—Miss Frances Mary Buss.

On March 8th, 1938:—

*Honorary Companion.*—Miss A. Baden-Powell.

*Fellow.*—Basil Wilmot Townshend (from Associate Fellow).

*Associate Fellows.*—Rio Nusservan Mirza (from Student), Alexander Phillips West (from Student), James George Willis, Emile Benjamin Wolff.

*Associate Members.*—Bernard Dudley Austen, Ralph Charles Pike (from Associate), Francis Joseph Soper, Felix Perceval Wills.

*Associates.*—Victor Ludwig Gruberg (from Companion), Eric Lane-Burslem, Reginald John Lawes, William Henry Riley (from Student), Charles Arthur Robinson.

*Graduates.*—Leslie Richard Eyre Appleton (from Student), John Somerville Gibb, Charles Peter Plantin (from Student), Henry Ernest James Rochefort (from Student).

*Students.*—Laxman Shriped Ajrekar, Eric Humphrey Barker, John Frederick Barlow, Henry Charles Brooker, John Raymond Bufton, Anthony Michael Creedon, William Hotchkiss Edwards, Emrys Richard Evans, William Patrick Ingram Fillingham, Laurie Frederick Fox, Jim Harvey, Kenward Ernest Knox, Owen George Lighton, Maurice McIverney, James McTaggart, Charles Henry Naylor, Patrick John Muriel Nettleton, Eugene Edward Schiff, Roy Ernest Stainton, James Taylor, Victor Albert Webb.

*Companions.*—Martin Cahill, Edward Silling.

On April 12th, 1938:—

*Fellows.*—Alfred Charles Barlow (from Associate Fellow), Alfred Charles Brown (from Associate Fellow), Roy Chadwick (from Associate Fellow), Henry Knowler (from Associate Fellow), Robert Talbot Youngman (from Associate Fellow).

*Members.*—Wallace Charles Devereux (already a Fellow), Frederick Handley Page (already a Fellow).

*Associate Fellows.*—M. W. S. Boucher, Rowland Henry Bound, John Thomas Brown, Alfred Hunter Crawshaw, James H. Doolittle, George Bertram Sainsbury Errington, Hugh Arthur Francis, Geoffrey William Hall, Henry Herbert Jackson, Horace Charles Luttman, William James Stuart King-Smith (from Student), Frederick Gerald Carlton Sandiford.

*Associate Members.*—James Richard Cole, Douglas Hilton-Grundy, Aendrea James Fotheringham McDonald (from Student).

*Associates.*—William Edward Clarke, Rosamund King-Everard (from Companion), Kenneth Ashton Hurst, Harold Robert Hughes Lyster, Louis Arbon Strange.

*Graduate.*—Herbert Priestley.

*Students.*—John Frederick Barlow, John Bloch, Geoffrey Peter Bridger, Allen Tancred George Daymon, John Edward Hawkins, M. J. D. Inskip, Peter Rainer Jeves, Robert Gordon Macleod, Donald George Maskrey, John Frederick Malcolm Moyle, Victor Neville Gordon Ralph, Eric St. John, Robert Thomas Wall, James William Warriss, Stuart Edward White.

*Companions.*—Robert Baines Holmes (from Student), Cecil Clifford Vinson, Miss Peggy Salaman.

On May 24th, 1938:—

*Fellows.*—Maurice Shadwell Hooper (from Associate Fellow), Maurice Edward Arthur Wright (from Associate Fellow).

*Associate Fellows.*—Maurice Joseph Brennan (from Student), Cecil George James Dunsford, William Clarence Jackson, Francis Ronald Rogers Lovell, John Macleay, Stanley George Evelyn Nash, Austyn Reynolds, Sydney Walter Slaughter (from Associate), Frederick William Stent.

*Associate Member.*—Noel Britton (from Associate).

*Associates.*—Foster Hickman Dixon, John William Greener, Clifford Hole, Peter Johnstone Jenkins, Roy Montgomery Lloyd, Sanghui Premchandraroy Samji.

*Graduates.*—Alan Wickham Giffard Birch, Harry George Sydney Peacock.

*Students.*—Hakan Blamburg, Li-Ming Chang, William Tait Dow, Jack Randall Lander, John William Layfield, Alfred William Mungovan, Robin Derrick Parkhouse, Harry George Radlett, John Miles Warner, Douglas Curling Friend.

*Companions.*—Hugh Campbell Adams, Lionel Mote, G. Wigham Richardson.

On June 21st, 1938:—

*Fellow.*—Charles James Prior Ball.

*Associate Fellows.*—Denys Chester Ford, John Kenneth Redman.

*Associate Member.*—John Rowland Harvey.

*Associates.*—Victor John Neyle, James Brunton Samson, Frank Squire.

*Graduates.*—Donald Clark Dundas.

*Students.*—Chandri Mohammed Afzel, John Vredenburg Inglesby, Peter Leyshon Martyn, Parsad Nair Narinjan, Hugh Frederick Payne, George Robert Pearson.

On September 13th, 1938:—

*Associate Fellows.*—Edward Tranter Barber (from Student), William Neville Cumming, Mohsen Shehab-el-Din (from Student), James Bruce Douglas, Charles Fisher, Maurice Hancock, Thomas Hanning Jackson, Bernard Joseph Lynch, Rachpal Krishen Nanda, Alastair Rennoldson Ross, Frederic Rowland Cooper Smith.

*Associate Members.*—Ronald George Buck (from Student), Robert English Cunningham, Stephen Augustus Evans, Clive Mersey Jones, John Edward Nicholas Larkin, Allan Thomas Oswald Liddell (from Student), Frederick Laurence Payne, Cecil Ruther Thorne, Howard Buckley Wilkinson (from Student), Edgar Quested.

*Associates.*—Bernard Horace Becker, George Arthur Day, Joseph Ashley Harris, Michael Chitty Clendon Haycraft, Joseph Healey, Andrew Colin Paul Johnstone, Richard Carew Reynell, William Fowler Peck Taylor.

*Companion.*—Leonard Seymour Werry (from Student).

*Graduates.*—Ray Miller Brown, Shirly Donald Dickins, Guy Clavell Ingo Gardiner, Albert Geoffrey Griffiths, John Burne Mills, David Macfarlane, Felix Robert James Spearman, George Ingram Sprent, Patrick Huia Wilkinson.

*Students.*—Frederick Barnes, George Wilson Brass, Albert Leonard Cattermull, John Bryan Cross, Sydney Arthur Conibear, Terence John Frederick Davey, Michael Dublin, John Squires Gadsby, Alexander Lindsay Gordon, William Sidney James Grant, James Carnegie Harris, Niall Patrick Heron, Edward Raymond Holdsworth, Frederick Arthur Houghton, Roy James, Frank Thomas Kiernan, John Derek Leicester, Robert Billie McIntyre, Kenneth Mitchell, George William Potts, Richard William Holroyd Quinton, Peter Meyrick Salter, Maurice Armstrong Smith, Geoffrey Clifford Stapleton, Herbert Titmuss, Gerald Robert Woollett.

On October 4th, 1938:—

*Associate Fellows.*—Howard Walter Barlow, Harry John Crampton (from Student), Albert Godfrey Gooch (from Associate), Bernard Kaiser, Arthur Theobald Mathews, Thomas Forster Naisby, John Lockwood Taylor.

*Associate Members.*—Frank Allsopp (from Student), Lewis James Mountjoy.

*Associates.*—Dennis Leonard James Armes, Arthur William John Hale.

*Companion.*—Vishnu Madhav Ghatage.

*Graduates.*—Dennis Bernard Peter, Duncan Ramsay, Felix Bowker Schofield, Lawrence Roy Wilson.

*Students.*—William Kenneth Austin, P. G. Barber, Dennis Gerald Brinjes, Stanley Charles Joseph Caliendri, Leonard Charles Alfred Coombs, Edward Chaloner Kirby Crowther, Sydney Davies, Edward William Fidler, Arthur Lawrence, George Rooney, Harry Hall Smith.

On November 16th, 1938:—

*Fellow.*—Harry Edgar Broadsmith (from Associate Fellow).

*Associate Fellows.*—Duncan Cameron (from Student), Eric Ian Campbell, Ian Bowman Fleming (from Student), Charles Willis Prower (from Student), William Frank Hilton (from Student), Ernest Ronald Stables, Eric St. John (from Student), Walter Tye (from Student), Alan Frederick Walsh (from Graduate).

*Associate Members.*—Sydney Allard (from Student), William Read Bendall, Charles Thorley Kimber, Ernest Robert Locke, Hugh Walker.

*Associates.*—Leonard Richard Ambrose, Cyril Hooper Edgecombe, Bernard Cecil Frost, Harry Hadfield-Langdon, Ronald Hector Longe, Anthony Christopher Loraine (from Student).

*Graduates.*—Wilfrid Michael Bentley, Ruben Hadekel (from Student), Ralph Marcus Hare, Andrew Keith Hunter (from Student), Douglas Ivor Husk (from Student), John Watson Leach (from Student), Frank Isaac Marking, Frederick William Page, Peter Shaw (from Companion), Mervyn Millington Waghorn (from Student).

*Companions.*—Frederic Greenaway Brown, Arthur Carpmael, Leo Frederic Alfred d'Erlanger, Joseph Cleverly Lister, William Mitchell Smart.

*Students.*—John William George Allen, Edgar Martyn Allies, Frank Oxley Baines, Desmond Rene Fitzgerald Barron, John Raymond Batty, B. H. M. Buck, John Alexander Fisher, Granville Clifford, Michael Marcus Isaiah Erdman, Henry Lafone Greenshields, Thomas Day Griffin, Patrick Harry Derek Hands, Owen Lewis Hyde, Julius Aloysius Jaeger, Roger Winter Jamieson, Humphrey Edwards Jones, Garth Owen Jones, James Kelly, Roy Kendall, Harold Arthur Lovell, Harold Luskin, Kenneth Lyon, Peter McGinn, Gerald Oke Manning, John Faulknor Pierce, John Gilbert Pippet, Elfyn John Richards, Alan Bryce Robertson, Albert Rose, Fayez Ebtenago Sahyoun, Donald Henry Shiley, Peter James Smith, Donald Lister Soutter, Frederick Vere Kent Sutton, Frederick Douglas Ward.

On December 7th, 1938:—

*Fellows.*—Albert Gillis von Baumhauer, James Edwin Ellor.

*Associate Fellows.*—Harold Alan Hamersley, James Clement Hornby, Peter Herbert Rayner (from Graduate), Alan Edward Richards (from Student), Henry Ernest James Rochefort (from Graduate), Hamish Murray Will (from Student).

*Associate Members.*—John Gilbert Olsen, William Thomas Wakeham (from Student), Harry Thomas Wood-Smith.

*Associates.*—Reginald William Allott, William Edward Baptist, William Howard Bell, Thomas Edgar Davies.

*Graduate.*—Robert Knight Page (from Student).

*Students.*—Peter Robert Allison, Paul Lionel Joseph Edwardes, Francis Guilbridge, Ronald Hills, Myer Julian Isador Kemper, Ronald Herbert Ponsford Nott, Richard Stallebrass.

*Companion.*—Godfrey Penington Kingdon.

FINANCE.

The Income and Expenditure Accounts and Balance Sheets of Aerial Science Limited and Aeronautical Trusts Limited for 1938 are published in this issue of the Journal.

The Income and Expenditure Account of Aerial Science Limited shows an excess of income over expenditure for the year of £269 8s. 4d. as against an excess of expenditure over income for 1937 of £47 4s. 5d. As in 1937 certain donations for the year have been placed to Capital Account.

JOURNAL.

The Income and Expenditure Account of Aerial Science Limited gives a summary of the expenditure on the Journal and sundry publications, *e.g.*, advance proofs of lectures, reprints of lectures, reprints of papers, etc. The Income and Expenditure of the Journal is as follows: (The figures in brackets are the corresponding figures for 1937.)

| | £ | s. | d. | £ | s. | d. | | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Printing Cost | 2,904 | 4 | 3 | (2,695 | 0 | 0) | Sales | 1,355 | 11 | 7 | (1,288 | 19 | 1) |
| Postages | 343 | 12 | 10 | ( 326 | 15 | 4) | Advt. | 2,271 | 1 | 9 | (1,919 | 10 | 9) |
| Other Charges | 591 | 18 | 2 | ( 453 | 1 | 8) | Rev. Loss | 213 | 1 | 11 | ( 326 | 7 | 2) |
| | £3,839 | 15 | 3 | (3,474 | 17 | 0) | | £3,839 | 15 | 3 | (3,474 | 17 | 0) |

Both the Sales and Advertisement revenue have risen and an increase of printing costs has followed the increasing circulation. Other charges include the cost of blocks, which was considerably heavier in 1938 than in 1937.

OFFICERS OF THE SOCIETY.

The Council wish to place on record their appreciation of the work which has been carried out by the Officers of the Society.

Major D. H. Kennedy, O.B.E., F.R.Ae.S., in 1938 completed 12 years' continuous service as Honorary Treasurer of the Society. Major Kennedy has always taken the keenest interest in the work of the Finance Committee and has been one of the most active members of the Committee during the whole period of his service.

Mr. A. N. D. Smith has for the 11th year in succession acted as Honorary Accountant to the Society and his advice and practical help has been invaluable on the Finance Committee.

Mr. L. A. Wingfield, the Solicitor to the Society, has freely placed his legal knowledge at the disposal of the Council and its Committees during the year. It has fallen to him to advise the Council on various important matters concerned with the taking over of No. 4, Hamilton Place and the leaving of 7, Albemarle Street.

The Council wish particularly to thank the Chairmen and Members of Committees of Council for their work on behalf of the Society during 1938.

The Finance Committee under the Chairmanship of Mr. W. C. Devereux; the Education and Examinations Committee and the Medals and Awards Committee of which Professor G. T. R. Hill is Chairman; the Lectures Committee, under Mr. A. H. Hall; and the House Committee under the Chairmanship of Mr. H. E. Wimperis, in particular, have relieved the Council of a very considerable amount of work, which has been heavier than usual now the Council have gone ahead with the plans for the new headquarters. The Society owes all these Committees a deep debt of gratitude for their voluntary work on its behalf. The Grading Committee, which does not have an appointed Chairman, has also done most invaluable work during the year, considering carefully every application for technical membership of the Society.

The Council would also like to thank those representatives of the Society on other bodies and Committees who have enabled the Council to keep in touch with the activities of other Institutions.

# THE ROYAL (Aerial

## *Balance Sheet,*

| | £ s. d. | £ s. d. |
|---|---|---|
| *Share Capital*— | | |
| *Authorised*— | | |
| 20 Shares of 1/- each ... ... ... ... ... ... ... | 1 0 0 | |
| 999 Shares of £1 each ... ... ... ... ... ... ... | 999 0 0 | |
| | 1000 0 0 | |
| *Issued*—19 Shares of 1/- each, fully paid.. ... ... ... ... | | 19 0 |
| *Sundry Creditors* ... ... ... ... .. ... ... | | 879 4 8 |
| *Subscriptions and Other Amounts Received in Advance* ... ... ... | | 480 17 0 |
| *Staff Pensions Fund* ... ... ... ... ... ... ... ... | | 203 2 0 |
| *Surplus*— | | |
| *Capital Accumulations Account*— | | |
| Balance at 31st December, 1937 ... ... ... ... ... ... | 4875 8 5 | |
| *Add*—Donations during year ... ... ... ... ... ... | 4875 8 5 | |
| | 9750 16 10 | |
| *Income and Expenditure Account*— | | |
| Balance at 31st December, 1937 ... ... ... 2603 10 11 | | |
| *Add*—Surplus of Income over Expenditure for year to date ... ... ... ... ... ... ... 269 8 4 | 2872 19 3 | 12623 16 1 |
| | | £14187 18 9 |

We report to the Members that we have examined the above Balance Sheet with the Books are of the opinion that the Balance Sheet is properly drawn up so as to exhibit a true and correct information and the explanations given to us and as shown by the Books of the Society.

3, Frederick's Place, Old Jewry, London, E.C.2.
20th February, 1939.

## *Income and Expenditure Account*

| | £ s. d. | £ s. d. |
|---|---|---|
| To Establishment Expenses— | | |
| Rent, Heating, Lighting and Insurance ... ... ... ... | | 931 15 8 |
| ,, Office and Staff Expenses— | | |
| Salaries ... ... ... ... ... ... ... ... ... | 1682 15 10 | |
| Printing and Stationery ... ... ... ... ... ... | 381 8 7 | |
| Postages ... ... ... ... ... ... ... ... ... | 268 2 2 | |
| Other Charges ... ... ... ... ... ... ... ... | 671 8 4 | 3003 14 11 |
| ,, Expenditure on Journal and Sundry Publications— | | |
| Printing Costs ... ... ... ... ... ... ... ... | 2904 4 3 | |
| Postages ... ... ... ... ... ... ... ... ... | 343 12 10 | |
| Other Charges ... ... ... ... ... ... ... ... | 591 18 2 | |
| | 3839 15 3 | |
| *Less*—Sales ... ... ... ... ... ... 1355 11 7 | | |
| Advertisement Revenue ... ... ... ... 2271 1 9 | 3626 13 4 | 213 1 11 |
| ,, Meetings ... ... ... ... ... ... ... ... ... | | 152 10 4 |
| ,, Library Expenses ... ... ... ... ... ... ... ... | | 42 10 0 |
| ,, Slides and Photographs ... ... ... ... .. ... ... | | 18 19 7 |
| ,, Prizes and Donations .. ... ... ... ... ... ... | | 5 5 0 |
| ,, Dinners and Receptions—Expenses ... ... ... ... ... | 322 5 4 | |
| *Less*—Receipts ... ... ... ... | 157 3 0 | 165 2 4 |
| ,, Legal and Professional Charges ... ... ... ... ... ... | | 200 8 0 |
| ,, Staff Pensions Fund... ... ... ... ... ... ... ... | | 100 0 0 |
| ,, Loss on Realisation of Investments ... ... ... ... ... | ... ... | 212 5 7 |
| ,, Balance, being Surplus of Income over Expenditure for Year to date, carried to Balance Sheet ... ... ... ... ... ... | | 269 8 4 |
| | | £5315 1 8 |

## *The Royal Aeronautical Society Endowment Fund*

| 1938 | | £ s. d. |
|---|---|---|
| Jan. 1. | Fund at commencement of year ... ... ... ... ... ... ... | 11474 3 7 |
| Dec. 31. | Investment Income during the year (including Tax Refund) ... ... ... | 415 2 4 |
| ,, | Entrance Fees during the year ... ... ... ... ... ... ... | 332 17 0 |
| ,, | Donations during the year ... ... ... .. ... ... ... ... | 1 11 0 |
| | | £12223 13 11 |

# AERONAUTICAL SOCIETY

## Science Limited)

### *31st December, 1938.*

| | £ s. d. | £ s. d. |
|---|---|---|
| *Office Furniture, Printed Books, Bindings, Old Prints, etc., at cost, less amounts written off* ... ... ... ... ... ... ... | | 50 0 0 |
| *Stock of* JOURNALS *and other Publications* ... ... ... ... ... | | 1 0 0 |
| *Sundry Debtors and Payments in Advance* ... ... ... ... ... | | 1722 2 2 |
| *Investments at Cost*— | | |
| £1504 15s. 11d. Manchester Corporation 3 % Red. Consd. Stock, 1952/55 ... ... ... ... ... ... ... ... ... ... | 1518 3 3 | |
| £2970 8s. 11d. 3½ % Conversion Loan ... ... ... ... ... | 3000 0 0 | 4518 3 3 |
| (Market Value at 31st December, 1938, £4,355) | | |
| *Investment in and amount due from Subsidiary Company—Aeronautical Trusts Limited*— | | |
| 21 Shares of 1/- each, fully paid, at cost ... ... ... ... | 1 1 0 | |
| Amount due on Current Account ... ... ... ... ... | 7390 14 0 | 7391 15 0 |
| *Staff Pensions Fund Investment, at cost*— | | |
| £188 3s. 11d. 4½ % Conversion Loan, 1940/44 ... .. ... ... | 200 0 0 | |
| Cash at Bank ... ... ... ... ... ... ... ... | 3 2 0 | 203 2 0 |
| *Cash at Bank and in Hand* ... ... ... ... ... ... ... | ... ... | 301 16 4 |
| | | £14187 18 9 |

of the Society, and have obtained all the information and explanations we have required. We view of the state of the Society's affairs as at 31st December, 1938, according to the best of our

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### *for the Year ending 31st December, 1938.*

| | £ s. d. | £ s. d. |
|---|---|---|
| By Annual Subscriptions ... ... ... ... ... ... ... | | 4520 19 6 |
| ,, Interest on Investments (*Less* Tax) ... ... ... ... ... | 214 6 2 | |
| ,, Interest on Deposit Account ... ... ... ... ... ... | 3 10 7 | |
| ,, Income Tax Recovered ... ... ... ... ... ... ... | 32 13 2 | 250 9 11 |
| ,, Interest on Endowment Fund Investments (*Less* Expenses) ... | 410 18 4 | |
| ,, *Less*—Transferred to Endowment Fund ... ... ... ... ... | 410 18 4 | – – – |
| ,, Donations ... ... ... ... ... ... ... ... ... ... | | 500 0 0 |
| ,, Examinations—Fees Received .. ... ... ... ... ... | 189 9 6 | |
| *Less* Expenses ... ... ... ... ... ... | 189 5 0 | 4 6 |
| ,, Garden Party—Receipts ... ... ... ... ... ... ... | 923 0 0 | |
| *Less* Expenses ... ... ... ... ... ... | 879 12 3 | 43 7 9 |
| | | £5315 1 8 |

### *(in the custody of Aeronautical Trusts Limited).*

| 1938 | | £ s. d. | £ s. d. |
|---|---|---|---|
| Dec. 31. | Expenditure during the year— | | |
| | Fee *re* Recovery of Income Tax ... ... ... ... | 4 4 0 | |
| | Loss on Sale of Investment during the year ... ... ... | 7 17 0 | 12 1 0 |
| ,, | Fund at close of year... ... ... ... ... ... ... ... | | 12211 12 11 |
| | | | £12223 13 11 |

# AERONAUTICAL

## *Balance Sheet,*

| | £ s. d. | £ s. d. | £ s. d. |
|---|---|---|---|
| *Share Capital*— | | | |
| *Authorised*—40 Shares of 1/- each ... ... ... | ... ... | 2 0 0 | |
| *Issued*—21 Shares of 1/- each fully paid ... ... | ... ... | | 1 1 0 |
| *Pilcher Memorial Fund*— | | | |
| *Capital Account*—As at 31st December, 1937 ... ... | | 99 14 0 | |
| *Income Account*—Balance at 31st December, 1937 ... | 38 5 8 | | |
| *Less* Excess of Expenditure over Income for year to date | 5 19 4 | 32 6 4 | 132 0 4 |
| *Usborne Memorial Fund*— | | | |
| *Capital Account*—As at 31st December, 1937 ... ... | | 109 2 5 | |
| *Income Account*—Balance at 31st December, 1937 ... | 45 9 0 | | |
| *Add* Income for year to date ... ... ... ... | 3 19 0 | 49 8 0 | 158 10 5 |
| *Herbert Akroyd Stuart Fund*— | | | |
| *Capital Account*—As at 31st December, 1937 ... ... | | 688 19 0 | |
| *Income Account*—Balance at 31st December, 1937 ... | 202 12 7 | | |
| *Add* Income for year to date ... ... ... ... | 23 18 0 | 226 10 7 | 915 9 7 |
| *R.38 Memorial Fund*— | | | |
| *Capital Account*—As at 31st December, 1937 ... ... | | 978 3 10 | |
| *Income Account*—Balance at 31st December, 1937 ... | 395 10 8 | | |
| *Add* Surplus of Income over Expenditure for year to date | 10 8 10 | 405 19 6 | 1384 3 4 |
| *Edward Busk Memorial Fund*— | | | |
| *Capital Account*—As at 31st December, 1937 ... ... | | 449 6 1 | |
| *Income Account*—Balance at 31st December, 1937 ... | 85 18 4 | | |
| *Less* Excess of Expenditure over Income for year to date | 1 8 6 | 84 9 10 | 533 15 11 |
| *Wilbur Wright Memorial Fund*— | | | |
| *Capital Account*—Balance at 31st December, 1937 ... | 1298 9 9 | | |
| *Add* Donation received during the year ... ... ... | 100 0 0 | 1398 9 9 | |
| *Income Account*—Balance at 31st December, 1937 ... | 126 5 5 | | |
| *Add* Surplus of Income over Expenditure for year to date | 8 7 6 | 134 12 11 | 1533 2 8 |
| *Simms Gold Medal Fund*— | | | |
| *Capital Account*—As at 31st December, 1937 ... ... | | 250 0 0 | |
| *Less—Income Account*— | | | |
| Deficiency at 31st December, 1937 ... ... ... | 39 3 6 | | |
| *Add* Excess of Expenditure over Income for year to date | 4 16 0 | 43 19 6 | 206 0 6 |
| *Royal Aeronautical Society Endowment Fund*— | | | |
| *Capital Account*—Balance at 31st December, 1937 ... | | 11474 3 7 | |
| *Add* Donations received during year ... ... ... | | 1 11 0 | |
| Entrance Fees received during year ... ... | | 332 17 0 | |
| Amount transferred from Aerial Science Ltd. ... | | 410 18 4 | |
| | | 12219 9 11 | |
| *Less* Loss on Sale of Investment during year ... ... | | 7 17 0 | 12211 12 11 |
| | | | £17075 16 8 |

We report to the Members of Aeronautical Trusts Limited, that we have examined the above explanations we have required. We are of opinion that the Balance Sheet is properly drawn up December, 1938, according to the best of our information and the explanations given to us and as

3, Frederick's Place, Old Jewry, London, E.C.2.
20th February, 1939.

# TRUSTS LIMITED

## *31st December, 1938.*

| | £ s. d. | £ s. d. |
|---|---|---|
| *Pilcher Memorial Fund—* | | |
| £115 6s. 10d. 3½ % War Loan at cost ... ... ... ... | 116 5 0 | |
| Cash at Bank ... ... ... ... ... ... ... ... | 15 15 4 | 132 0 4 |
| *Usborne Memorial Fund—* | | |
| £113 3½ % War Loan at cost ... ... ... ... ... | 114 11 1 | |
| Cash at Bank ... ... ... ... ... ... ... ... | 43 19 4 | 158 10 5 |
| *Herbert Akroyd Stuart Fund—* | | |
| £683 1s. 0d. 3½ % War Loan at cost ... ... ... ... | 698 19 0 | |
| Cash at Bank ... ... ... ... ... ... ... ... | 216 10 7 | 915 9 7 |
| *R.38 Memorial Fund—* | | |
| £1048 11s. 2d. 3½ % War Loan at cost ... ... ... ... | 1098 18 10 | |
| Cash at Bank ... ... ... ... ... ... ... ... | 285 4 6 | 1384 3 4 |
| *Edward Busk Memorial Fund—* | | |
| £284 4s. 2d. 3½ % War Loan at cost ... ... ... ... | 284 4 2 | |
| £217 London Transport 4½ % "A" Stock, at cost ... ... | 199 4 6 | |
| | 483 8 8 | |
| Cash at Bank ... ... ... ... ... ... ... ... | 47 18 7 | |
| Amount due for refund of Income Tax ... ... ... ... | 2 8 8 | 533 15 11 |
| *Wilbur Wright Memorial Fund—* | | |
| £1246 18s. 1d. 3½ % Conversion Stock, at cost ... ... ... | 1000 0 0 | |
| £550 Canada 4 % Stock, 1940/60, at cost ... ... ... ... | 531 10 9 | |
| | 1531 10 9 | |
| Cash at Bank ... ... ... ... ... ... ... ... | 8 10 5 | |
| Amount due for refund of Income Tax ... ... ... ... | 5 10 0 | |
| | 1545 11 2 | |
| *Less*—Amount owing to Aerial Science Limited ... ... ... | 12 8 6 | 1533 2 8 |
| *Simms Gold Medal Fund—* | | |
| £287 16s. 1d. India 4½ % Stock, 1958/68, at cost ... ... ... | 250 0 0 | |
| Cash at Bank ... ... ... ... ... ... ... ... | 25 18 0 | |
| | 275 18 0 | |
| *Less*—Amount owing to Aerial Science Limited ... ... ... | 69 17 6 | 206 0 6 |
| *Royal Aeronautical Society Endowment Fund—* | | |
| *Leasehold Property at Cost—* | | |
| 4, 8, and 9, Hamilton Place, London, W.1 ... ... ... | 7918 12 6 | |
| *Investments at Cost*— | | |
| £2504 2s. 8d. 3½ % Conversion Stock ... ... 3192 5 1 | | |
| £4100 London & North-Eastern Railway 3 % Debenture Stock ... ... ... ... 3162 6 3 | | |
| £3100 London, Midland & Scottish Railway 4 % Debenture Stock ... ... ... 3162 19 9 | | |
| £862 16s. 8d. Manchester 3 % Loan, 1952/55... 870 9 8 | | |
| £629 16s. 4d. London County Council 2¾ % Loan, 1960/70 ... ... ... ... 600 0 0 | 10988 0 9 | |
| Cash at Bank ... ... ... ... ... ... | 585 0 2 | |
| Amount due for refund of Income Tax ... ... | 104 6 6 | |
| | 19595 19 11 | |
| *Less*—Amount due to Aerial Science Limited ... 7308 8 0 | | |
| Amount owing for Legal and Professional Charges ... ... ... ... ... ... 75 19 0 | 7384 7 0 | 12211 12 11 |
| *Cash in Hand* ... ... ... ... ... ... ... ... | | 1 1 0 |
| | | £17075 16 8 |

Balance Sheet with the books of the Company and have obtained all the information and so as to exhibit a true and correct view of the state of the Company's affairs as at 31st shown by the books of the Company.

(Signed) PRICE, WATERHOUSE & CO

# AERONAUTICAL

## INCOME & EXPENDITURE ACCOUNTS

### *Pilcher*

| | £ s. d. |
|---|---|
| To 1938 Awards ... ... ... ... ... ... ... ... ... ... ... | 10 0 0 |
| | £10 0 0 |

### *Usborne*

| | |
|---|---|
| To Income for year carried to Balance Sheet ... ... ... ... ... ... | 3 19 0 |
| | £3 19 0 |

### *Herbert Akroyd*

| | |
|---|---|
| To Income for year carried to Balance Sheet ... ... ... ... ... ... ... | 23 18 0 |
| | £23 18 0 |

### *R.38*

| | |
|---|---|
| To 1938 Award ... ... ... ... ... ... ... ... ... ... ... | 26 5 0 |
| ,, Surplus of Income over Expenditure for year carried to Balance Sheet ... ... | 10 8 10 |
| | £36 13 10 |

### *Edward Busk*

| | |
|---|---|
| To 1938 Awards ... ... ... ... ... ... ... ... ... ... ... | 21 0 0 |
| | £21 0 0 |

### *Wilbur Wright*

| | |
|---|---|
| To 1938 Award ... ... ... ... ... ... ... ... ... ... ... | 50 0 0 |
| ,, Surplus of Income over Expenditure for year carried to Balance Sheet ... ... | 8 7 6 |
| | £58 7 6 |

### *Simms Gold*

| | |
|---|---|
| To 1938 Awards ... ... ... ... ... ... ... ... ... ... ... | 17 15 0 |
| | £17 15 0 |

### *Royal Aeronautical Society*

| | |
|---|---|
| To Legal Charges ... ... ... ... ... ... ... ... ... ... | 4 4 0 |
| ,, Surplus of Income over Expenditure for year transferred to Aerial Science Limited | 410 18 4 |
| | £415 2 4 |

# TRUSTS LIMITED

## FOR THE YEAR ENDED 31st DECEMBER, 1938.

### *Memorial Fund.*

| | £ s. d. |
|---|---|
| By Interest on Investments (gross) ... ... ... ... ... ... ... ... | 4 0 8 |
| ,, Balance of Expenditure over Income for year carried to Balance Sheet ... ... | 5 19 4 |
| | £10 0 0 |

### *Memorial Fund.*

| | |
|---|---|
| By Interest on Investments (gross) ... ... ... ... ... ... ... ... | 3 19 0 |
| | £3 19 0 |

### *Stuart Fund.*

| | |
|---|---|
| By Interest on Investments (gross) ... ... ... ... ... ... ... ... | 23 18 0 |
| | £23 18 0 |

### *Memorial Fund.*

| | |
|---|---|
| By Interest on Investments (gross) ... ... ... ... ... ... ... ... | 36 13 10 |
| | £36 13 10 |

### *Memorial Fund.*

| | |
|---|---|
| By Interest on Investments (*less* Tax)... ... ... ... ... ... ... ... | 17 2 10 |
| ,, Refund of Income Tax ... ... ... ... ... ... ... ... | 2 8 8 |
| ,, Balance of Expenditure over Income for year carried to Balance Sheet ... ... | 1 8 6 |
| | £21 0 0 |

### *Memorial Fund.*

| | |
|---|---|
| By Interest on Investments (*less* Tax) ... ... ... ... ... ... ... | 52 17 6 |
| ,, Refund of Income Tax ... ... ... ... ... ... ... ... ... | 5 10 0 |
| | £58 7 6 |

### *Medal Fund.*

| | |
|---|---|
| By Interest on Investments (gross) ... ... ... ... ... ... ... ... | 12 19 0 |
| ,, Balance of Expenditure over Income for year carried to Balance Sheet ... ... | 4 16 0 |
| | £17 15 0 |

### *Endowment Fund.*

| | |
|---|---|
| By Interest on Investments (less Tax) ... ... ... ... ... ... ... | 310 15 10 |
| ,, Refund of Income Tax ... ... ... ... ... ... ... ... ... | 104 6 6 |
| | £415 2 4 |

## Obituaries.

The Council record with deep regret the deaths of the following members during the year:—

Mr. M. Atkinson Adam, B.Sc., F.I.C., Founder Member.
Mr. R. P. Alston, B.A., Associate Fellow.
Captain F. S. Barnwell, O.B.E., A.F.C., Fellow.
Mr. Colin C. Byar, Student.
Mr. H. M. Gardiner, Student.
Group Captain G. B. Hynes, D.S.O., R.A.F., Founder Member.
Mr. Kyoichi Nosawa, Student.
Mr. R. V. Peacock, Student.
Flight-Lieut. W. F. Pharazyn, Associate Fellow.
Mr. R. B. Ringwood, Associate Member.
Flying Officer K. D. Salmon, Associate Member.
Mr. Norman Sandham, Student.
Mr. J. Saycatch, A.M.I.E.E., A.I.Mech.E., Member.
Wing Commander F. W. Stent, M.C., R.A.F. (Retd.), Associate Fellow.
Mr. A. C. Stevenson, M.I.A.E., Associate Fellow.
Mr. K. Wilks, Student.
Mr. T. W. Willis, Member.

### Group Captain G. B. Hynes.

Group Captain George Bayard Hynes, D.S.O., F.R.Ae.S., died on May 30th, 1938. At the time of his death he was Deputy Director in the Directorate of Aeronautical Inspection at the Air Ministry.

Group Captain Hynes was one of the early pioneers in British Aircraft. He learned to fly at Hendon in a Bleriot monoplane, taking his Royal Aero Club certificate (No. 40) in December, 1910. In 1911, then a lieutenant in the Royal Garrison Artillery, he was appointed to No. 2 Company, the Air Battalion, Royal Engineers, at Larkhill on Salisbury Plain and took part in the Army manœuvres of that year. In 1912 he was flying a Breguet biplane and flew one of these machines to France on the outbreak of war. He was mentioned five times in despatches and awarded the D.S.O. in 1917.

He was appointed to the command of an engine repair depot at Pont de l'Arche, and there his natural flair for engineering had full play. In 1919 he commanded the Mechanical Repair Depot at Shrewsbury, in 1921 was appointed as Chief Experimental Officer (Engines) at Farnborough and attended as Principal Technical Officer. In 1927 he was appointed as Chief Inspector (Engines) in the A. I. D. and Deputy Director in 1936.

One of the most unassuming of men, and a man of great personal charm, Hynes not only had the knack of getting the best out of all those who served under him, but of earning a very real affection given to few. He earned that, too, by his own high quiet efficiency which set an example for others to follow.

### Captain F. S. Barnwell.

Captain Frank Sowter Barnwell, O.B.E., A.F.C., B.Sc., F.R.Ae.S., was killed on August 2nd, 1938, while flying a small low-wing monoplane of his own design. By his death aviation lost one of its most brilliant aircraft designers.

Educated in Scotland, Captain Barnwell and his brother Harold, built a biplane as long ago as 1908. Frank Barnwell later went to the Bristol Aeroplane Factory,

and his brother Harold to Vickers Ltd. Frank Barnwell's first success was the Bristol Bullet. It was followed by the historic Bristol Fighter and many others, including the Bristol Bulldog and Bristol Blenheim.

An outstanding designer, Captain Barnwell was a man of great personal charm whose ability was respected by all those who came in contact with him. He was a meticulously careful worker and the aircraft which he produced set a high standard throughout the world. No one did more to advance the cause of aviation from the pioneering days to the day of his death.

### R. P. Alston.

Richard Peter Alston was killed on February 16th, 1939, while flying with Squadron Leader R. T. Cazalet. R. P. Alston, who was only 33 years of age at the time of his death, had already made a name for himself as a keen experimental worker engaged on full-scale research. He was a member of the Cambridge University Air Squadron 1926-29, and in 1928-29 carried out full-scale aerodynamic research under Professor B. Melvill Jones. In the latter year Alston joined the Aerodynamic Department of the Royal Aircraft Establishment, and in December, 1934, read a paper before the Society on Wing Flaps and other Devices or Aids to Landing, a paper which led to a very able discussion.

## REVIEWS.

### Trade Marks.

By Reginald Haddon. Published by Sir Isaac Pitman and Sons, Ltd. Price 5/-.

This book has been written for the purpose of explaining the alterations in the law concerning trade marks which have been embodied in the new consolidated law, the Trade Marks Act, 1938. The author is a Fellow of the Chartered Institute of Patent Agents.

The subject is of considerable interest to those concerned with these marks, and it is obvious that since considerable alterations have been made in the law, that there is room for a book which explains exactly what these alterations are and how they affect the owner of or applicant for trade marks. The subject is dealt with in considerable detail, and the complicated rules for renewals of registration are described fully. One is inclined to agree with the author that these rules might well be simplified. This is a book which should be most useful to those concerned.

### The Testing of Metallic Materials.

By Ernest Skerry, M.I.E.I. Published by Bunhill Publications, Ltd. Price 3/6.

This short book contains a reprint of articles on metallic testing which originally appeared in "Aircraft Engineering." The subjects discussed are tensile testing, hardness testing and impact testing, with descriptions of the more usual types of machines used for these purposes. There is also a section on extensometers, ductility tests, bending tests, magnetic and torsion tests.

Within its rather limited scope this book should be quite useful to those engaged in the normal methods of testing materials. The methods given for obtaining proof tests will be novel to some testers and should facilitate greatly the carrying out of this test. It is noted that the Izod test is regarded principally as a method of indicating whether heat treatment has been correctly carried out. This, of course, is generally true with regard to the materials which are normally tested in this way, but the true function of this test is to measure the resistance of the material to the spreading of a crack. That this type of resistance often depends on a particular type of heat treatment, as in the case of Krupp Krankheit is incidental. In certain types of structural parts, where, owing to the necessities of design, sharp discontinuities of section are difficult or impossible to avoid Izod tests should invariably be carried out on the material.

The book should appeal to those concerned with its subject matter and it is well supplied with diagrams and illustrations. It is good value for 3/6.

### Aeronautical Meteorology.

By George F. Taylor. Published by Sir Isaac Pitman and Sons, Ltd. Price 18/-.

The author of this book is Chief Meteorologist to the Western Air Express Corporation and it naturally deals with meteorological matters from the point of view of the U.S.A. There is a chapter dealing with European weather, but the feature of the book which is of particular interest is the manner of approach. Instead of discussing the subject in terms of cyclones and anticyclones, the treatment is practically confined to movements of air masses and to the various kinds

of fronts. These air masses are labelled by symbols as to their origin and history, for instance, a mass which has originated in Alaska, Canada, or the Arctic Ocean, is called Polar Canadian and is labelled Pc, while if the mass originates in the Gulf of Mexico it is called Tropical Gulf, shortened to Tg. The future of each mass is then discussed and the changes in humidity and temperature caused by the movement of each mass from, say, a colder to a warmer sea, or from sea to land, are described. In every case a paragraph is always added for the information of the air pilot, describing the flying conditions that may be expected, such as whether the particular mass is likely to be bumpy, or whether icing conditions are likely to be met with.

Icing conditions generally come in for considerable attention and ice formation is divided into three types, frost, rime and clear ice, in which only the latter constitutes a real danger to aircraft. He describes the dangerous mushroom ice formation as being due to large droplets which spread out while freezing, but it is not easy to see why this action should necessarily lead to formations of this type.

It is interesting to hear that horizontal wind velocities in the neighbourhood of a tornado may amount to as much as 300 or 400 miles an hour and that there may be vertical velocities of 200 miles an hour, while in the case of hurricanes 150 miles an hour seems to be a maximum. The tornado disturbance must produce the highest wind velocities known if these figures are correct and one can well understand the advice given to pilots to keep well clear of them.

Generally the book is of considerable interest, but it is unfortunate that the weather conditions discussed are not of immediate importance to Europeans. If Mr. Taylor could provide a work on these lines dealing with meteorological matters here it would certainly be valuable. As it stands, the book is an important one and should be invaluable to those desiring to study American meteorological methods and American weather.

THE PRINCIPLES OF MOTOR FUEL PREPARATION AND APPLICATION.

By Alfred R. Nash, M.Sc., and Donald A. Howes, B.Sc. Vol. I. Price 36/-.

This is the first volume of the second edition of this well known work, and it has been found that some of the material in the first edition is now out of date. Hence, a number of additions and alterations have been made and a chapter on Pyrolysis and Polymerisation has been added.

The general scope of this volume is the production of motor fuels by distillation, cracking, extraction from natural gas and hydrogenation. It also deals with benzole, alcohol fuels, synthetic fuels, etc., and methods of storage are described.

The modern aero engine depends largely for the improved thermal efficiency which it shows on the use of special fuels, and any further increase of efficiency must depend on further fuel improvements and, hence, on the skill of petroleum chemists. It is impossible to peruse this book without being impressed with the skill and ingenuity of the workers in this field, and with the remarkable results which have already been obtained. A mere list of the various catalysts used, often mixed together with promoters and other additions, would be formidable in itself, and when one learns that the behaviour of each of these is generally accurately known and that the type of reaction which it assists has been ascertained, it is possible to obtain some idea of the amount of knowledge which has been accumulated.

To those interested in the production of liquid fuels this work should be indispensable, but it should also be most valuable to those engaged in work on internal combustion, who will find in it a detailed description of practically every motor fuel on the market. Those who are interested in improved fuels which may result in better engines will also find much to interest them.

KURT QUEITSCH: "SCHWEISSTECHNIK IM FLUGZEUGBAU" (Welding Technique in Aircraft Construction). Lehrblaetter fuer die Technische Ausbildung in der Luftwaffe (Manual for the Technical Instruction in the Air Force). Berlin, 1938. Publ. by Dr. M. Matthiesen and Co. 217 pp. with 195 fig. and 2 tabl. Price R.M. 3.80.

This instruction manual is intended for the service instruction of aircraft welders, but the designer may find it useful. An introductory chapter refers to the different kinds of welding, including electrical resistance welding. Gas welding is thoroughly treated in a subsequent chapter. Besides the acetylene procedure, hydrogen and benzole welding are dealt with. With regard to benzole-oxygen welding it is stated that it cannot be recommended for aluminium, but gives excellent results with magnesium alloys. Right and left hand welding are discussed, the former being recommended for steels thicker than approximately 10 S.W.G. The different metals and practical workshop tests for the welding qualities of uncertain materials are dealt with in an excellent way. Deformations and internal strains due to welding and the intelligent prevention of such defects are explained most clearly. Highly instructive examples show how to obtain the minimum of deformation in welded steel parts and structures. This chapter is the result of long experiments dealing with welding shrinkages. The designer who so often discovers that welded components follow their own laws in a very annoying way will here find many valuable hints. The manufacture of welded steel fittings with and without fixtures, aluminium alloy tanks, air ducts, light alloy fittings, mountings for radial and in-line engines, tail group structures and tubular fuselages, etc., are described with a number of good examples taken from different German aircraft firms. A final chapter refers to workshop control and to inspection.

To the knowledge of the reviewer there does not exist any other treatise dealing with all aspects of modern aeronautical welding practice which can claim to be so up to date and so really instructive than this little manual.

DR. ALFRED GERBER: "UNTERSUCHUNGEN UEBER GRENZSCHICHTABSAUGUNG" (Research with Boundary Layer Suction). Vol. 6 of "Mitteilungen aus den Institut fuer Aerodynamik, Eidgen. Techn. Hochschule Zuerich" (Reports of the Aerodynamical Institute, Federal Technical University, Zurich). Edited by Prof. D. J. Ackeret. Zurich, 1938. Publ. by A. G. Gebr. Leemann and Co. 70 pp. with 60 fig. Price Swiss Frcs. 5.50.

After a short introduction into the nature of the boundary layer, the author describes his experimental research work with suction slots in a wind tunnel. He has found a suitable method for the comparison of different arrangements by the use of artificially thickened-up boundary layers which allow for bigger sizes of slot models, therefore eliminating the influence of small inaccuracies in shape and installation. It is well known that the results obtained by sucking away of the boundary layer depend to a big extent on slot shapes. The thickening-up of the boundary layer is obtained by installing rough walls in the tunnel. The tests indicate that—contrary to O. Schrenk's opinion—there is reason to be more optimistic as to the amount of suction required. A series of further tests refer to the influence of boundary layer suction on the airflow along a wall while changing its direction. This is shown by the author as an analogy to the airflow along the contour of an aerofoil, in simplification of the experimental arrangement. These tests have been made in an open wind tunnel of the Eiffel type, with an artificially thickened-up boundary layer. The results of the tests prove the possibility of a reduction of the drag inherent to thick aerofoil sections, as a consequence of the removal of the boundary layer near the trailing edge.

An appendix refers to wind tunnel tests on Joukowsky aerofoil sections of 30 per cent. thickness fitted with a leading edge slat and a Fowler flap. With

the basic section the maximum lift coefficient was 1.38. With the Fowler flap alone $C_{L\ max}$ rose to 3.59 at an incidence of 4.45°, while with slat and Fowler flap a $C_{L\ max}$ of 4.19 was obtained at 10° incidence with a drag coefficient of appr. 1.06.

DR. K. KRIEGER: "FLUGZEUG-LEICHTMETALLBAU" (Aeronautical Light Alloy Construction). "Lehrblaetter fuer die Technische Ausbildung in der Luftwaffe" (Manual for the Technical Instruction in the Air Force). Berlin, 1938. Publ. by Dr. M. Matthiesen and Co. 168 pp., 200 fig., one colour and numerous other tables. Price R.M. 4.20.

This manual is obviously compiled by an engineer with a wide workshop experience in aeronautics. It treats the different light alloys and their properties (no less than 113 alloys are listed), workshop methods for recognising unknown alloys, workshop installation tools and machine tools (including riveting, welding and soldering implements, metal beating tools and presses), the workshop practice with light alloys (cutting, bending, beating, jaggling, folding, bordering, drawing, welding, soldering, riveting, including explosive rivets and repair work on riveted structures, machining of light alloy parts, sheet metal work, heat treatment, surface protection, etc.). The peculiarities in working the different alloys are described in subsequent parts of the book with valuable data as to machining speeds and pitches, tables for the calculation of weights, standard specifications, etc.

The manual is extremely well written, gives many instructive samples and illustrations, and the practical designer would find it as useful as the man on the bench.

VIEWS ON AIR DEFENCE.
By Lieut.-General N. N. Golovine in collaboration with a Technical Expert. Published by Gale and Polden, Ltd. Price 5/-.

This book consists of a series of articles originally published in the "Royal Air Force Quarterly." It consists of a technical study of air attack and air defence, and, as such, appears at an opportune moment.

It is reasonable to suppose that there are few problems connected with the fighting Services which have caused more controversy than this one, whether in an air attack the bomber, as some think, will always get through; or whether an adequate defence can cause so many casualties to the attacker that the attacks will be discontinued as being too expensive.

A number of books exploiting the former point of view have already been published, and the public has been treated to elaborate descriptions of great cities wiped out by a hail of bombs, populations extinguished by poison gas, etc., so that many really believe that the bomber is unbeatable and that there is nothing before us in the next war but to submit.

To those who think in this way this book can be thoroughly recommended. It is not drawn up on sensational lines, but it is a clear logical treatise intended in the first place for the information of the R.A.F. All forms of air defence are discussed, the use of barrage balloons, attacking aircraft and A.A. guns, and it is interesting to note that the authors prefer guns of much larger calibre than anything we have in use to-day.

The conclusion which the authors arrive at after this study of the subject is that attacks on properly defended cities are likely to lead to little damage to the city and much loss to the attackers. This opinion is backed up by references to the happenings in the Great War. It is true that aircraft have vastly improved since then, but so have the guns and other means of defence, and, further than that, there has been time for intensive study of the problems involved and for the training of personnel and the provision of material. On the whole, it may easily be more dangerous to operate a bomber in the next war than in the

last, but even in the last the dangers of attacking defended areas were considerable.

Our own independent Air Force, during its raids on German territory in the Great War, lost 48 per cent. of its crews per month in daylight and 23 per cent. in night raids. In 1918, 483 bombers attempted to attack Paris, but only 37 actually arrived over the city. On one night only three out of 50 succeeded. Facts such as these show what can be done with a properly organised defence.

It can be taken as an axiom that a bomber which is being attacked, either by shell fire or hostile aircraft, will find accurate bombing impossible. In fact, experience shows that under these conditions the bombs are often dropped on inferior targets and the bomber turns for home. Speculation about what is likely to happen in possible future wars is seldom borne out by results, but it is at least possible that in such a case the centre of London could be made so unhealthy for raiders that it would be one of the safest places to live in.

ENGINEERING APPLICATIONS OF AERIAL AND TERRESTRIAL PHOTOGRAMMETRY. Capt. B. B. Talley. Pitman and Co. Ltd., 32/6.

It has long been a complaint that the literature of aerial survey and photography is so scattered, but Captain Talley seeks to remedy this and he does it most successfully in an encyclopædic work of some 600 pages.

His treatment is exhaustive, and after epitomising the historical background in the introduction, he covers all the ground from the camera and materials to the finished map. He draws on his own experience and no point escapes mention.

The section on cameras is so comprehensive that the omission of any reference to the Air Survey Committee's 7-lens camera seems strange especially when details have been published in at least three technical journals. The section devoted to the multiplex projector is very thorough and should prove of interest to those devoted solely to British practice, though it is a pity that the anaglyph referred to is not included. The illustrations have been chosen with care and in many cases they are stereoscopic pairs so arranged that they may be viewed stereoscopically.

References are given throughout in the text and in the many footnotes so that anyone requiring further information on any point knows where to find it. Two indexes are included, one of names, so that quick reference is facilitated.

One can unhesitatingly recommend Capt. Talley's book as one of the classics of literature of air survey. All the matter is concisely dealt with, and the author has not had recourse to padding.

DIPL.-ING. H. L. STUDER: EXPERIMENTELLE UNTERSUCHUNGEN UEBER FLUEGELSCHWINGUNGEN (Experimental Research on Wing Flutter). DR. SC. TECHN. P. DE HALLER: LA PORTANCE ET LA TRAINEE INDUITE MINIMUM D'UNE AILE AU VOISINAGE DU SOL (Lift and Minimum Induced Drag of a Wing Near the Ground). Vol. 4/5 of "Mitteilungen aus dem Institut fuer Aerodynamik, Eidgen. Hochschule Zuerich" (Reports of the Aerodynamical Institute Fed. Techn. University Zurich). Edited by Prof. Dr. J. Ackeret, Zurich, 1936. Publ. by A. G. Gebr. Leemann and Co., 98 pp. with 65 fig. and num. tabl. Price Swiss Frcs. 10.-.

The first part is a valuable experimental study of the wing flutter problem. In 1933, the author began—together with Prof. J. Ackeret—wind tunnel research work with elastically mounted wing models. These tests proved that the critical dynamic pressure (or the critical speed) depends to an overwhelming extent on the angle of incidence, and that the minimum critical dynamic pressure occurs at the angle of no-lift and at or very near the stalling angle of incidence. Further research showed that this phenomenon is caused by delays occurring in the separation of the airflow, while the wing is oscillating, so that, by a kind of hysteresis effect, an existing oscillation is agitated.

The author concludes that two definite forms of wing oscillation exist, namely one acting in accordance with Birnbaum's theory for stationary air flow conditions (B-oscillations), while the other is existing under non-stationary air flow conditions at very small and at very large incidences (no-lift and stalling) and is characterised by a much lower critical dynamic pressure (A-oscillations). Obviously, the latter form is of greater importance.

The author's research work has been restricted to the two-dimensional case with two degrees of freedom (bending and torsion of wing), while the influence of ailerons is being neglected. A Reynolds number of 300,000 has been adopted. The experiments refer to three aerofoil sections (Goettingen 538, Clark Y and Goettingen 535). Flexural and c.g. axis could be shifted between fairly wide limits. The intensity of the increase of the oscillations has been closely watched. For causing an instability, an initial disturbance of two degrees was employed.

The results of these tests prove the large influence of the angle of incidence. Aerofoil thickness and camber also influence the critical speed (section Goettingen 535 being the poorest). A-oscillations at negative angles of incidence (dives) are especially important; the remedy being a *small* increase of the incidence effected by the pilot. Constructionally, the author recommends: Aerodynamical balance and mass balance of ailerons; no cambered aerofoil sections near the wing tip; aerofoil thickness restricted as far as stiffness requirements permit; no washout at wing tips; aerofoil sections with no c.p. travel near wing tip; high torsional stiffness of wing systems; flexural and c.g. axis far forward; unequal basic frequences. The pilot is advised to avoid an abrupt entering into a dive and an abrupt flattening-out.

With regard to the fact that in a number of wing flutter accidents pilots have failed to jump by parachute or to throttle down, while experiencing dangerous flutter, the author hints that the pilot may have become stunned because of these severe oscillations, and he refers to physiological research done by *Reiher* and *Meister* (" Die Empfindlichkeit von Menschen gegen Erschuetterungen ").

The English literature on wing flutter is fully taken into consideration.

*De Haller's* paper is a theoretical investigation based on *Daetwyler's* work and refers to the case of a thin wing having flat or arc-shaped sections, near the ground. For infinite span, the theory predicts a decrease of lift near the ground for large incidences (15°—16°) and, for smaller incidences, an increase. For the case of definite span, the induced drag is smaller near the ground and the lift distribution becomes more centred.

R. Schnitzler: Luftverkehr (Air Traffic). Vol. 14 of " Luftfahrt-Lehrbuecherei." Berlin, 1938. Publ. by Dr. M. Matthiesen and Co., 40 pp., 11 figs., 1 map. Price RM. 1.25.

The author, a high official of the German Air Ministry, discusses generally the past and present of air traffic from geographical, political and economical aspects. Germany's air routes are considered in a special chapter. Aims for the future are seen in transpolar air routes and in high altitude flying. Technical problems are not touched. Unfortunately, as representative types of British transport aeroplanes, three obsolete types have been chosen, while the Frobisher and the Empire Boat class are omitted. Otherwise, an instructive and well-informed introduction into the general problems of the world's air traffic.

Dr.-Ing. H. Katz: Der Flugmotor, Teil I, Bauteile und Baumuster (The Aero Engine, Part I, Components and Types). Vol. 7 of " Luftfahrt-Lehrbuecherei." Berlin, 1938. Publ. by Dr. M. Matthiesen and Co., 301 pp., 296 figs., 9 tabl. Price RM. 4.80.

This book, compiled by a staff engineer in the German Air Ministry, describes parts, components, accessories and assemblies of German aero engines. The Junkers compression ignition engines are included. Also included is a description of the Armstrong Siddeley Panther VII engine (with the manufacturer's name

omitted), while otherwise no other engine of non-German origin is mentioned. Accessories such as starters, carburettors, magnetos, fuel pumps, superchargers, etc., but not radiators and exhaust systems, are thoroughly dealt with.

The book comprises a good detailed description of current German types, with good photographic reproductions, sketches and drawings. It is written for instructional purposes and intended for the engine mechanic. But it might also be of use to engine designers wanting information with regard to German aero engine practice.

DR. E. PREISWERK: ANWENDUNG GASDYNAMISCHER METHODEN AUF WASSERSTROEMUNGEN MIT FREIER OBERFLAECHE (Application of Methods of Gasdynamics for Waterflows with Unobstructed Surface). Vol. 7 of "Mitteilungen aus den Institut fuer Aerodynamik, Eidgen, Hochschule Zuerich" (Reports of the Aerodynamical Institute, Fed. Techn. University Zurich). Edited by Prof. Dr. J. Ackeret. Zurich, 1938. Publ. by A. G. Gebr. Leemann and Co. 130 pp., 85 figs., 4 tabl., 5 charts. Price Swiss Frcs. 8.80.

This paper refers to the relations between the flow of compressible fluids and non-compressible fluids with a free (*i.e.*, non-restricted) surface. Theoretical fundamentals and practical examples are treated with a full discussion of the theory of the two-dimensional supersonic gas flow. The results of experimental research work are incorporated. Special charts (two for air and three for water) facilitate the graphical representation of two-dimensional flows. The experimental part refers to the behaviour of boundary layers in channels and jets. The direct application of the laws of aerodynamics to the flow of water will be of special value for civil engineers dealing with hydraulic problems. The aeronautical engineer will find in this book a good and modern conception of the laws governing aerodynamics at or beyond the velocity of sound.

H. WENKE: WAEGUNGEN, SCHWERPUNKT, LADEPLAENE (Weighings, Centre of Gravity Position Finding, Loading Schemes). Vol. 7 of "Praktische Theorie in der Flugtechnik." Berlin, 1937. Publ. by Dr. M. Matthiesen and Co. (formerly by Dr. Max Gehlen, Leipzig)., 64 pp., 37 figs., 5 form sheets. Price RM. 4.-.

The author, an engineer with the Junkers works, deals in this booklet with practical methods of obtaining weights of aeroplanes and seaplanes, for finding the c.g. of a complete aircraft, and for the calculation of loadings in accordance with given c.g. positions. Form sheets are included in order to facilitate the practical procedure. All essential points are discussed and valuable hints given.

The weighing of bulky aircraft components such as wings on several balances, and the finding of the c.g. of these components are also dealt with. For the latter purpose the graphical method is preferred against the analytical one, because of its accuracy. Incidentally, the method given for a comparison of c.g. positions for different aeroplane types should be described as a very approximate one, one of the assumptions being the equality of the lift distributions over the span.

The booklet should be of interest for everybody who has to take weights and to perform measurements on complete aircraft.

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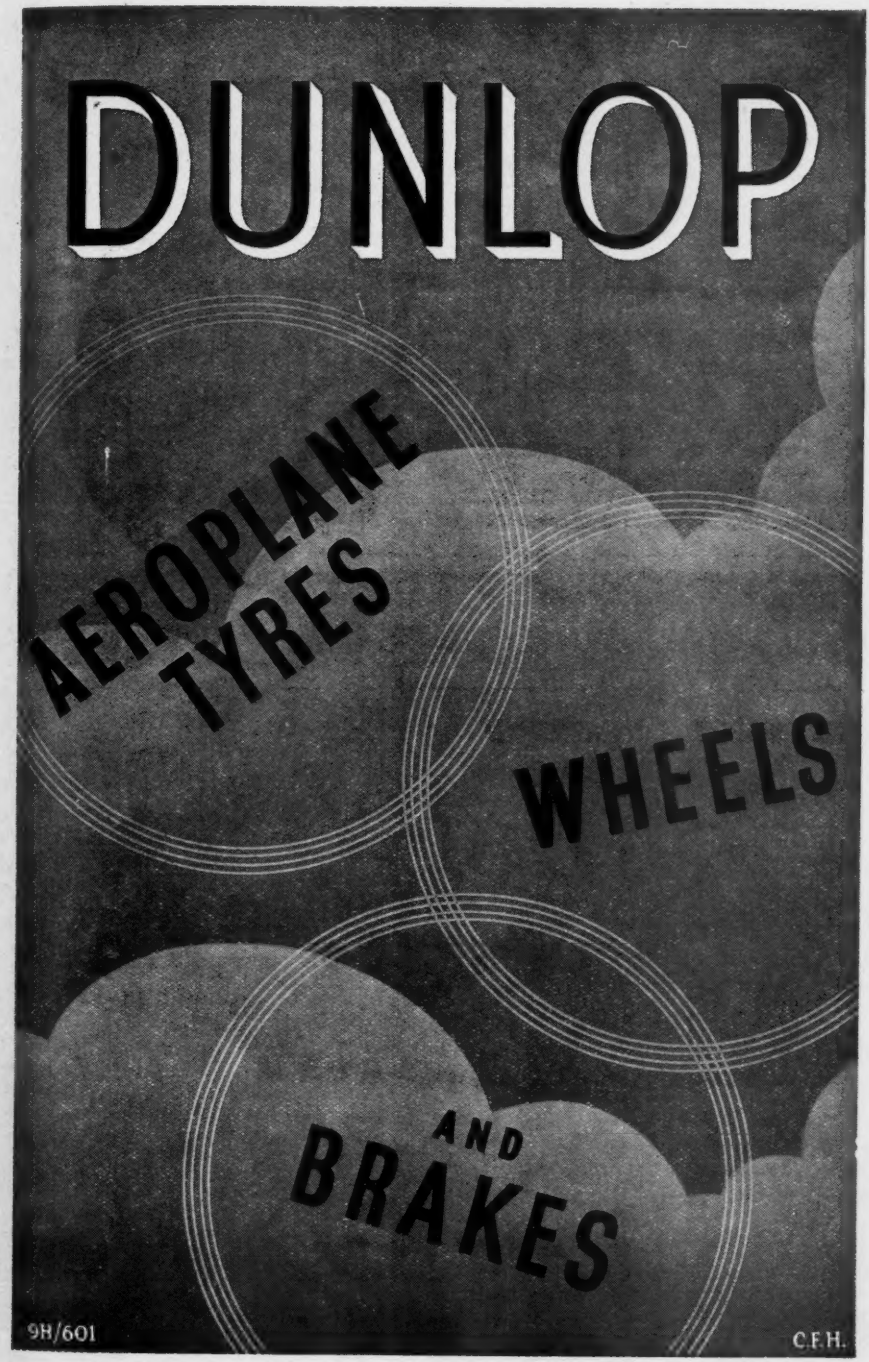
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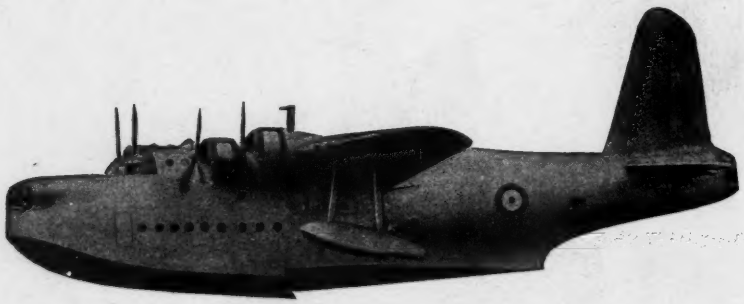

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## PROCEEDINGS.

A Meeting of the Society was held in the Lecture Hall of the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, on Thursday, October 20th, 1938, when a paper was presented by Mons. R. Le Coeuvre on "The Use of Light Alloys in Aircraft Construction."

In the Chair: Mr. W. C. Devereux, F.R.Ae.S., Member of Council.

THE CHAIRMAN: Mons. Le Coeuvre was already well known in this country. He had directed for eight years the Metallurgical Laboratory of the Technical Experimental Institute of Issy Les Moulineaux. The work of that Institute had been concerned with light metals, and particularly with the subjects of riveting, vibrations, the fatigue of metals and the micrographic examination of light alloys; and Mons. Le Coeuvre had published works on those subjects. He had been attached for ten years to the "Services des Fabrications de L'Aeronautique" in connection with the light metal industry; he was serving on the Technical and Industrial Directorate of the French Air Ministry, and he was also a pilot. For 12 years he had been Chairman of the French Committee on Corrosion of Metals (The President of which Committee was formerly Inspector-General Grard, who died recently. The President is now Mons. Caquot). Mons. Le Coeuvre is Professor of Metallurgy at l'Ecole Nationale des Moteurs and Professor of Studies for Metals and Alloys at l'Ecole Nationale Superieur de l'Aéronautique.

Mons. LE COEUVRE: The Royal Aeronautical Society had done him the great honour of asking him to deliver a lecture on the use of light alloys in aircraft construction; he had accepted the invitation with pleasure. The light alloys were to him old friends, and their use had extended not only to aircraft construction, but also to the railways and to motor cars; their development would extend still further.

## THE USE OF LIGHT ALLOYS IN AIRCRAFT CONSTRUCTION.

By Monsieur R. LE COEUVRE.

*(Translated from the French.)*

### INTRODUCTION.

Light alloys now play a most important part in aircraft construction. It is probable that they will keep their present superiority over other materials which have been in use, because manufacturers are continually adapting light alloys to the need of the day.

Light alloys have, however, formidable rivals. There are many arguments for the use of wood, and we must recognise that in certain aspects (such as resistance to vibration and ease of working) the use of wood has definite advantages, particularly in the case of plywood.

Plastic materials, which can be moulded to any required shape and only acquire their hardness after treatment, may well find great openings in aircraft construction. Such materials are already being used in the manufacture of various airscrew blades.

But, from a practical point of view, if it is intended to speed up production, and further the development of aviation by lowering costs and time of labour, one is automatically led to the judicious use of metals.

Statistics have shown that by developing tools and by making use of metal construction on a large scale, it is possible to lower the working time on any unit by a considerable amount. Metal construction must not, however, slavishly copy that of wood. One must only adapt ideas and processes of manufacture.

In metal construction itself, light alloys still have rivals.

Heavy alloys, such as:—

Special steels,
Stainless steels,
Monel metals, etc.,

are the objects of constant research and improvement.

Their characteristics are improving, and taking account of their greater density, their strength/weight ratio can at times exceed that of light alloys.

If, on the grounds of lightness, light alloys are used in small thicknesses, giving rise to doubt as to the rigidity or fear of local failure, it is possible to remedy the difficulty by " corrugating " the materials, the corrugations being of appropriate depth.

In fact, light aluminium alloys and ultra-light magnesium alloys are a great advance on other materials.

If their technical development falls in with the requirements of aircraft manufacturers, and if the production methods which they necessitate are in accord with needs in aircraft construction, a great future can be guaranteed for them.

At the present time, it seems that the light metal industry and the aircraft industry are intimately connected with each other. On economic grounds as well as on technical grounds the development of one must have inevitable repercussions on the evolution of the other.

In Part I of this paper, we are going to give a summary of recent developments which have received the approval of industry.

In Part II, we shall try to analyse tendencies in the matter of research by considering what appears to us to be of immediate and direct interest to constructors. We shall attempt to give the producers an idea of the needs of users. (Qualities to seek and pursue from a technical point of view.)

Finally, in Part III, we shall touch on the question of costs, and we shall try to show from previous conclusions how it is possible to reach a rational and economical way of giving a new impulse to the development of aviation by the use of light metals.

## Part I.

### Recent Industrial Development.

*A. Use of Light Alloys in Engines.*

Light alloys were formerly used in the " as cast " condition. Pistons, crankcases, and cylinder heads were in general of an aluminium-copper alloy, containing about 10 per cent. of copper. The strength of such alloys was of the order of $6\frac{1}{2}$ to $7\frac{1}{2}$ tons per sq. in. (10 to 12 kg. per m.$^2$) at a temperature of 20°C.

Their elongation and resilience were practically speaking nothing. The use of Alpax had produced a strength of about 10 tons per sq. in. (19 kg. per sq. m.) with 5 per cent. elongation.

### Improvements in Characteristics by Heat and Cold Treatment.

For some time now there has been a considerable improvement.

The alloys used for crankcases are more complex containing additional elements such as titanium which produces finer grain. These additional elements have the very important property of being able to give by heat treatment, and without any mechanical treatment, strengths of $18\frac{1}{2}$ to 21 tons per sq. in. (35 to 40 kg. m.$^2$) at 20°C. For equal dimensions, the safety factor is increased.

Further, the repair of a crankcase which has deteriorated in service becomes possible by a welding process (" soudure a la poche ") which is technically per-

fectly satisfactory, provided that the operation is followed by the appropriate heat treatment.

The characteristics of magnesium alloys, too, have improved. In particular, good results have been obtained at high temperatures (up to 300°C.) by the addition of silver or of cerium.

### Development of the Pressure Die Casting Foundry and of Press Forging.

Besides this purely technical progress, the equally important improvement in conditions of production must be remembered.

1. By the use of pressure die casting for magnesium alloys and certain aluminium alloys used for carburettor bodies.

2. By press-forging in large quantity certain parts such as pistons. In the case of pistons, the hardness obtained by heat treatment is not permanent at the temperature at which they work, since this corresponds to the annealing temperature. These parts come finished from the machine, and no further machining is necessary.

A superficial skin, like a hard and resisting film is formed all over the part.

### Compression During Solidification.

Certain large parts are subjected to pressure during solidification, in an autoclave.

The grain is then finer, and characteristics are generally improved.

Interesting experiments on this subject have been carried out at the Institute of Foundry Research at l'Ecole Superieure de Fonderie, in Paris.

### The Use of Light Alloys in the Airframe.

Light alloys are used for structural members (tubes or sections) for rolled sections (sheets and strips) for stampings (aluminium alloys and magnesium alloys) and as castings (magnesium alloy wheels).

It is safe to predict that aeronautical construction will tend more and more towards the use of sheet and strip.

It is the most economical means of using the material.

One avoids unnecessary scrap. The metal keeps its superficial skin. Strip metal is a simple product. Its storage in rolls is the least cumbersome. No finished part has greater safety than a piece of formed or welded sheet without discontinuities.

The use of extrusions is equally advantageous.

In order to reduce the number of different sizes and shapes as much as possible, tubes may offer a simple solution.

### Forming.

Machine forming of steel parts means the making of most elaborate dies.

For working light metals, it is possible to achieve very accurate production without the use of tools too costly for the quantity of production met with in aeronautical engineering.

In this way it is possible to replace steel dies with zinc ones* into which the sheet is thrust by means of a rubber pad. In case of modification the material can be remelted and used for the new die.

### Methods of Assembly.

It is in assembly and mounting that there is still plenty of room for development.

High duty alloys, such as duralumin, cannot be welded, assembly being done by riveting. A technique of riveting light alloys has been evolved in the course of the last few years and can be summarised as follows:—

* Magnesium alloy dies are now being made and also wooden dies which are steel faced.

The riveting is generally done cold up to $\frac{5}{32}$in. diameter (4 mm.). The rivets are put in in the normal state. The snap heads are cold hammered.

Above $\frac{5}{32}$in. diameter (4 mm.), the rivets are put in as soon as possible after quenching in order to take advantage of the consequent malleability of the metal.

In order to prolong this malleability, the rivets may be kept at a temperature of $-10°$C., the age hardening is interrupted and only takes place when the metal is allowed to return to normal temperature.

There are actually three operations in riveting:—

1. Drilling the sheet.
2. Putting the rivet in place.
3. Hammering.

Machines are in existence which in special cases will perform all three operations (aero-station use of rivet wires of small diameter).

These riveting machines are necessarily cumbersome, and up till now have only been constructed as fixed machines

The part therefore has to go to the machine, and not, as would be more logical, the machine to the part.

The invention of a portable machine which would do the three operations would make an interesting study, as would also the study of a portable welding machine, to which we will refer later.

### Advent of Aluminium-Magnesium Light Alloys.

The advent of aluminium-magnesium light alloys has opened out new possibilities to constructors.

Broadly, these alloys have two very important advantages: (1) They are weldable, (2) they are non-corrodible by sea water.

These properties may be put down to their greater homogeneity of structure, and the complete absence of copper.

Industrially, they can be looked upon from two aspects.

1. *Alloys containing less than 7 per cent. of magnesium.*

The ultimate tensile stress of these materials is of the order of 20-23 tons/sq. inch (32-36 kg./mm.$^2$).

Elongation is of the order of 25 per cent. These properties are obtained after annealing, the metal being improved by heat treatment.

Forming, bending, and drawing are done cold on annealed metal. The metal is amenable to deep drawing without damage.

The metal may also be worked hot, since its properties are not in any way due to quenching and as soon as the metal cools to the surrounding temperature, the original properties of the annealed metal return.

Autogenous welding presents no difficulties, but an appropriate flux must be used.

Every trace of the flux must, however, be removed after welding, otherwise there is risk of corrosion.

2. *Alloys containing 7 to 9 per cent. of magnesium.*

The properties of these alloys resemble very closely those of the well known alloys. The ultimate tensile stress is of the order of 27 tons per sq. inch (42 kgs./mm.$^2$). Elongation is of the order of 25 per cent..

But these properties are obtained by both heat treatment and quenching.

The quenching is done from a temperature of about 450°C. Between 150° and 350° the metal becomes brittle and it is better not to allow the metal to remain long in this temperature zone. This is a serious inconvenience, because the constructor may want to heat the material to just such a temperature in order to bake certain enamels or varnishes.

Forging and drawing operations may be done cold on quenched metal. But they are preferably done hot. A final operation of quenching gives the highest qualities to the material.

Autogenous welding is quite convenient, but the strength of the welded joint is definitely inferior to welded joints of base metal.

It appears that aluminium-magnesium alloys are capable of great improvement by some additions (notably of titanium) even in very small proportions.

The magnesium content can in this case be increased with advantage.

These improved alloys have, however, not been developed beyond the laboratory scale up to the present. The properties of stability and weldability would be retained.

THE USE OF MAGNESIUM-RICH ALLOYS.

The alloys of magnesium are used in the cast condition in the various members of the landing gear, wheels, equipment and various supports, and also in the forged condition for airscrews, and the drop forged condition for such parts as levers.

They are employed as sheet for the construction of tanks and welded parts in general. The strength values obtained on the sheets can be as much as 18 to 20.5 tons/sq. in. (28-32 kgs.), with 10 to 14 per cent. elongation.

The alloys of magnesium are easy to weld. This property makes them valuable to designers. The construction and repairing of the material is thus simplified considerably.

The washing after welding to remove all traces of flux should be very carefully done.

The possibilities of application of the alloys of magnesium in aircraft construction are limited to a certain extent by their sensitivity to the corrosive action of moisture, sea water and marine atmosphere.

To remedy this, numerous investigations have been pursued, and the users are informed of a certain number of measures to be taken to ensure for the material good stability.

A good protective treatment applied just after leaving the mould in the case of castings, and just after leaving the rolling mill in the case of sheet is necessary and adequate for guaranteeing stability in the subsequent treatments.

These protective treatments are achieved by immersion in boiling liquids.

Designers naturally prefer cold methods. It must be borne in mind that in the course of successive manipulations (machining, forging, etc.) particles of the protective film are removed. It is necessary to " maintain " the protection.

All the same, in the welding shop, when the sheets have been assembled by welding, the protective film has disappeared in the vicinity of the seam and it is essential to renew it immediately.

Some very interesting methods have been studied in Great Britain. We make particular reference to those of Lews and Evans (cold solutions) and those of Sutton and Le Brocq, as well as to the method of Bengough and Whitby, using arsenious acid.

Apart from these dipping treatments, we must remark on the activity which has been displayed recently in various countries in connection with processes of anodic protection.

A certain number of these have proved efficacious and have here and there taken their place in industry.

From the standpoint of efficiency, there is little to choose between the electrolytic treatment and the dichromate dipping treatment.

The surfaces so prepared are further treated with " finishes " (lacquers and enamels), baked or unbaked, according to the finish required. Excellent finishes have been produced, and help to give good stability to the material.

C.1. The Applications of Light Alloys in the Construction of Seaplane Hulls and Floats.

For the construction of the hulls and floats of seaplanes, the assemblies should be not only strong, but also *watertight*.

In the riveted assemblies the watertightness is achieved by interposing between the assembled elements plastic joints, or simply strips of strong paper, insulating the sheets by two coats of bituminous paint or zinc white paint.

In time, under the action of variations of temperature or under the action of vibrations, the joints dry up and contract. The grip of the rivets becomes unreliable, the watertightness is not certain, corrosive sea water penetrates the interior of the hull, remains there and causes disaggregations.

The Uses of Vedal or Alclad.

Vedal or Alclad have the advantage of standing up better to sea water than do alloys of the duralumin type, hence the favourable position which they occupy in the construction of hulls and floats.

It is, however, necessary to mention that the Vedal assembly cannot be achieved without the use of riveting with rivets of the duralumin type of alloy. Due to this fact, there arises between the rivet heads and the main sheeting heterogeneities which give rise to electrolytic couples, which prejudice the corrosion-resistance of the assembly.

Research on watertightness points to the employment, as in the above case, of plastic joints.

The need for stability necessitates the application of insulating and protective surface treatments.

The appearance of the aluminium-magnesium alloys can effectively facilitate the task of designers of hulls and floats.

Autogenous welding gives a first rate solution of the problem of watertightness.

Electric resistance welding, although it has given rise to misapprehensions, seems capable of giving satisfactory results when the conditions have been studied.

The problem of repairing is also considerably simplified by it.

The corrosion-resistance of seaplane floats and hulls is naturally a subject of constant study.

Electrolytic Effects which Arise.

Inasmuch as the welding processes have not been made general, it is not apparent how perfectly homogeneous assemblies can be obtained.

The material of which the rivets are made cannot be absolutely the same as that of the assembled sheets.

Moreover, the exigencies of construction sometimes require assembling of elements of different nature, *e.g.*, the fixing of a steel shoe to a light alloy float, or of a reinforcing ring to a light alloy hull.

Whatever precautions are taken to assure the electrical insulation of the junction, there is no doubt that the manufacturing processes give rise to circumstances which cause corrosion.

In order to avoid these situations, it has been suggested that elements of metals less noble than those in contact should be inserted at various points. In the special case of a steel-light alloy junction, zinc and cadmium are suitable for this purpose.

The electrolytic actions so produced lead to the progressive destruction of the additional element while giving the joint a protection as efficient as it is vigorous, and which admirably satisfies the requirements.

The process (metal spraying?) by which it is possible to affix to a given point, small amounts of pulverised additional elements, like zinc, without it being necessary to bore rivet holes to fix them, is particularly suitable for remedying this defect.

By means of this, it is not only possible to fix the initial masses, but it is remarkably easy to maintain them.

### Desiderata for the Designers.

In conclusion, it is obvious from a survey of the above field that a good technique has actually been established for using light alloys, and the precautions which may be taken for their successful utilisation, even in the sea.

The appearance of weldable light alloys with good resistance to sea water is such as to facilitate to a great extent the task of the designers, allow simplifications in the manufacturing processes, give a greater homogeneity in the assemblies and, finally, increase the potentialities of production.

It is, however, necessary to mention that the alloys which satisfy the requirements of weldability and stability have properties much inferior to the better known light alloys.

The designer willingly accepts the new advantages but is not willing to " pay " for them by sacrificing the high properties. He requires of metallurgists that they should make the necessary effort to procure the ideal alloy which will embrace all these advantages.

It is satisfactory to report an appreciable improvement in the fatigue limit in the course of deductions made during fabrication. Since this property is so important from the point of view of stability and safety it is essential for the progress to continue and for the aluminium-magnesium alloys to be able to share in this improvement.

It is pleasant to think of simplifying production methods, but before embarking upon a new technique it is desirable for them to be studied first in detail, and that the technique of the electric welding processes should be put upon a secure experimental basis.

The finest results obtained are those concerned with the stability of the alloys which give satisfaction in this respect, but the question arises as to whether or not the passivity conferred upon the alloys could not be made more complete by the introduction of certain additional elements, and whether the principles established for the light alloys could not be extended with success to magnesium-rich alloys.

We shall attempt in the second section to prophesy in what directions the research will move, as it bears upon the different points.

## Part II.

### Directions in which Research will Move.

### The Improvement of the Properties of Aluminium-Magnesium Alloys and in Particular the Fatigue Limit.

Investigations are actually being pursued to discover how to improve the mechanical properties while retaining the welding properties and stability unchanged.

MM.Canac and Segol have, by making special additions, been able to obtain in the laboratory alloys with very much higher properties.

The use of base metals of very high purity can contribute to a great extent in raising the fatigue limits. A very remarkable degree of purity can be obtained by using Hoopes cells for aluminium and the sublimation processes invented by MM. Chaudron and Herenguel in the case of magnesium.

The liberation of gases and the prevention of blow holes are also factors which can contribute to some extent to the raising of the fatigue limits.

### The Establishment of a Good Technique of Electric Welding.

The spot or seam electric welding of light alloys is a difficult problem. The difficulties arise from :—

(1) The high electrical and thermal conductivities of the metal. These tend to limit the passage of current to a very short time and to the employment of currents at very high tension.

The order of these data is as follows:—

Density ... ... ... 50,000 amperes.
Time ... ... ... 1/10-1/1000 second.

However, according to Hibert* good results would have been obtained with considerably different data:—

Density ... ... ... 5,000 to 30,000 amperes.
Time ... ... ... 10 periods (or about $\frac{1}{5}$ sec.).

(2) The relatively low fusion point of the metal.

(3) The presence of an oxide film between the joined ends.

(4) Corrosion hazards caused by the use of copper electrodes and the necessity to change these electrodes very frequently.

In this respect, tests carried out with chromium electrodes seem to give more satisfactory results.

The pressure of the electrodes on the pieces is a very important factor which also has its effects upon the other properties. If it is excessive, it produces on the surface a local cold working effect which can become independently a cause of corrosion. If, however, it is too low, the point extends over all the thickness of the sheet, and forms a series of pores and cracks.

Generally speaking, the results obtained with the "aluminium-magnesium" alloys are better than those with the "duralumin" type alloys.

The behaviour of assemblies under dynamic stresses and vibrations has been the subject of very many researches.

We shall mention particularly the comparative tests on welded test pieces and riveted test pieces carried out at the Bayerische Flugzeugwerk,† and also the tests performed in the Laboratories of the Establissement d'Experiences techniques d'Issy les Moulineaux (Mlle. Doussin).

The doubts which might have been entertained *a priori* on the behaviour of assemblies when subjected to vibrations can apparently be dispelled.

The very important part played by the current density is noteworthy.

For a convenient density, the actual weld is completely internal. The outside surface cooled by the electrodes never reaches the fusion point. The melted part solidifies in a sort of crucible made up of the non-melted parts of the sheet.

If the density is very low, the melted zone is slightly expanded or suffers a loss in mechanical strength.

If, on the other hand, it is too high, the crucible is broken and the molten metal reaches the surface. The electrodes are damaged and corrosion results. Systematic macrographic tests performed on sheets of almasilium 1 mm. thick have demonstrated very clearly the effects of the current density on the shape and size of the joints.

### Heat Treatment Following Electric Welding of Aluminium-Magnesium Alloys.

From the viewpoint of electric welding, the use of aluminium-magnesium alloys has a marked advantage over that of alloys of the duralumin type. The part of the metal, the structure of which has been altered by the welding, can have its structure restored by heat treatment. In this way one can hope to obtain a more uniform structure in the complete assembly, and increase the individual mechanical strength of each point, as well as the resistance to dynamic stresses.

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* Charles A. Hibert. "Spot Welding of Aircraft Materials," Weld J.B.17, 1938.

† F. H. Hintzen-Augsburg. Die Elektrische Funktschweissung von Duraluminkonstruktions in Flugzeugbau (The Electric Welding of Duralumin Structures in Aircraft Construction). Luftwissen, August, 1938.

The actual achievement of the treatments on the large assemblies raises other problems which have not, to my knowledge, yet been solved.

The placing of large light alloy assemblies in the heating chamber has always been avoided, because the long time at a temperature higher than 150°C., involves a general lowering of the mechanical properties. The employment of stoving lacquers, particularly hot polymerised bakelite resins, has always been avoided (due to this fact) in the protection of high strength members.

This danger does not exist for the aluminium-magnesium alloys of low magnesium content. In the case of alloys of 8 per cent. magnesium, it has been shown that a fragile zone exists between 150 and 350°C., and it is necessary to avoid keeping the alloy too long in this section.

Industrially, the two operations, heat treatment of the assembly and stoving after protection, could be effected simultaneously in the course of one period in the furnace.

One would thus be inclined to produce, for aircraft construction, stoving installations, similar to those which exist for automobile construction. Attempts to apply aluminium-magnesium alloys in car construction are actually in progress. It is very obvious that if the attempts to use heat treated resistance welded alloys give full satisfaction, the extension to aircraft construction could be made immediately.

### The Watertightness of Welded Seams.

Tests have been performed in order to obtain watertight assemblies (floats, tanks, etc.) by seam welding. These experiments have not always given satisfaction.

This question deserves to be the subject of a special experimental investigation.

Although the parts are not joined at the surfaces, it should be possible, in the welded seam, to arrange the heating zones to a degree sufficient to assure that a continuous line is produced and, consequently, that the weld is watertight.

The doubling of the welded seam would appear to constitute a good precautionary measure.

Objection has often been made to welding machines because they are cumbersome and stationary. It is suggested that it is the machine which should go to the metal part and not vice-versa.

I am glad to be able to say in this respect that the technique of welding machines has developed considerably in the last few years, and improvements to them are being made constantly.

There exist in industry portable spot welding tongs, hydraulically driven, with double action, which have the advantage of decreasing the weight and bulk of the head.

On the other hand, the cylinder motor can be mounted on a C-shaped frame. The lower electrode is fixed on a horizontal axis so that it can be counterpoised in order to remove the pieces. The transformer and the control system are separate from the tongs, but are connected to them

### Welding Control.

The radiographic control over the welds is a process which has been applied for a long time.

By a suitable filtering of the rays and an appropriate choice of the incidence to be given to the exploring rays, it is possible to show up very slight differences on the image and expose extremely fine flaws.

It is to be noted that the generating units are becoming more and more portable, and lend themselves more and more to the control of large pieces, even on the factory scale of production.

Research on Stability in Sea Water.

Research on automatically protected alloys, *i.e.*, those resistant to corrosion *without any surface treatment*, exposed to sea water has been pursued with increasing enthusiasm in every country for more than 15 years.

The work of Dr. Evans, Professor Bengough, Sutton, and other eminent British scientists has thrown a particularly vivid light on the question of corrosion.

In France a Research Commission was established in 1925, with the respected expert Inspector-General Grard as President, to study specially the questions of corrosion (M. Grard died last year).

The work of the Commission is actually carried out under the direction of President Caquot.

The work of this Commission, in which eminent savants and engineers participate, is published periodically, and shows the evolution of the ideas on the subject.

Aluminium is not a noble metal. It occupies in Nernst's scale a very low position, between iron and zinc, but it is possible to confer an " acquired nobility " on aluminium and its alloys. By introducing into the base metal, even in traces, suitably chosen constituents the particles of which are very finely divided, even if they are less noble than the base metal, it is possible to obtain on the surface a continuous film which confers passivity on it in a given reagent, in this case sea water. The formation of this film can be accelerated by introducing an applied electromotive force, such as operates when the part is subjected to anodic treatment. In cases of local damage, the protective film re-forms itself automatically when the alloy is immersed in the reagent for which it was developed (sea water in the present case).

The composition of the alloy can be chosen in such a manner that the film, by its nature, thickness and constitution has adhesive properties, impermeability, and the electrical resistance necessary to assure adequate protection of the coated metal.

In order to establish the relationship between the properties of the protective coating and the structure of the metal, several correlated ideas are involved.

(1) The necessity for having the base metals extra pure, so the simple, well-defined alloys can be formed, in which the additional elements can be easily identified.

(2) The laws of Pilling and Bedford enable us to discover in advance, from the respective densities of the metal and its oxide, whether or not the oxide film will be protective and whether or not there will be contraction, porosity, discontinuity, or lack of efficiency.

(3) The need to clean and polish the base metal; it is necessary to take note of the topography of the metal underneath, *i.e.*, its state of polish, which plays an important part in the formation of the film. The latter is adherent in proportion as the primary structure of the recently alloyed elements is close. The " Solex " micrometer and M. Canac's diffusionmeter could find a wide and profitable field of investigation here.

(4) The necessity for measuring precisely the thickness of film required.

In general, it has been discovered that thin coatings, *e.g.*, invisible films, of which the thickness is less than the wave-length of visible light rays, are the most flexible, most adhesive and, consequently, the most protective.

The mechanical properties of the film so formed, with or without the bringing into play of external E.M.F.'s, are still little known.

The suppleness, *i.e.*, the power of the films to undergo important deformations without rupture, can play a very important *rôle* in the corrosion fatigue fracture phenomena. One could conceive that if, at each reversal, there is fracture in the protective film, when the frequency of alternation is so large that the film has not time to rebuild itself, corrosion will increase rapidly the crack which the rupture causes.

The velocity of re-formation of the film at fracture is thus yet another factor operating, and one particularly interesting to study. A relationship should exist between this speed and the resistance to corrosion fatigue. This speed could itself be a function of the state of division (more or less large) of the addition elements in the base metal.

This simple treatment gives an idea of the extent of the field of investigation which is open to research in this connection.

### Researches Concerning the Auto-Protection of Magnesium-Rich Alloys.

These researches are of considerable interest to aircraft construction. It is possible that the improvement in the mechanical properties could be connected with the reduction in stability.

## Part III.

### Future Developments in the Use of Light Alloys in Aircraft Construction.

The collected information on the progress which has been made, which we have reviewed here, seems to have prepared the ground admirably for an adaptation to manufacturing processes with a view to very important developments in production.

Scarcely twenty years ago the automobile industry was still using complicated manufacturing processes involving much hand work and high production costs.

A French designer, M. Dewoitine, undertook a very exhaustive investigation on the subject of increasing the output of the automobile industry by the use of machine tools. He obtained the figures shown in the following table:—

| Period. | Type of Construction. | Working Hours per Unit. | Power per Worker in Ch. | No. of Workers per Unit per day. |
|---|---|---|---|---|
| 1920-2 | Composite ... ... ... | 900 | 0.2 | 110 |
| 1925-7 | Drawn sheet wooden frame ... | 400 | 0.4 | 50 |
| 1930 | Sheet and frame ... ... | 150 | 2 | 19 |
| 1936 | Welded monocoque structure... | 95 | 3 | 12 |

It may be seen from this table that the time taken has been reduced from 10 to 1, while the power produced has increased in the ratio of 1 to 15. What has happened to the car could be extended to aircraft construction. It is the most certain way of obtaining decreased production costs.

It could be objected that the working time necessary for the fabrication of the body only represents a very small fraction of the total time necessary, the most important part being spent on the assembly and equipment.

Experience has shown conclusively that in an assembly of mean tonnage the working times are in the following ratio:—

| | |
|---|---|
| Purely mechanical work ... ... ... | 15% |
| Semi-mechanical work ... ... ... | 25% |
| Assembly and mounting ... ... ... | 60% |

Efforts have already been made to reduce the time necessary for installing the equipment. Division of labour could help here, but for the principal frame elements of the structure, the idea possible for a factory determined to carry it out would amount to the following:—

The almost exclusive use of weldable light alloy sheet and strip. A structure composed of standardised pressed members, provided in large quantities sufficient for the fabrication and subsequent replacements.

The principal plant of the factory would be:—

Power drawing presses for forming large surfaces.

Drawing presses of the normal type for working small pieces.

Electric welders for making assemblies with the minimum of hand work. (Stationary and, particularly, portable welders.)

Bending presses.
Ordinary welding machines and machine tools.
Shears.
Band saws.
Planing machines, etc.
Large electric furnaces for heat treatment and recovering the properties of the welded joints.
Large baths for the anodic treatment of these assemblies.
The use of the " chignolle " and the portable punch should be excluded.

CONCLUSION.

The preceding considerations lead to the conclusion that the producers of light alloys should make the necessary efforts in order to be able to put at the disposal of the users alloys of high strength, which acquire their maximum mechanical properties without quenching heat treatment, by simple annealing, and possessing good welding properties and resistance to sea water.

With such alloys the users could have a chance to equip their factories for intensive production. In these factories, the drawing presses and the portable welding machines would be used in the main part of the fabrication. It should be mentioned that the initiation of mass production would necessitate preliminary investigations with close collaboration between the laboratory, the factory and the research department.

The professional education of the executive personnel is one of the factors, and not the least important, of those to be examined. The work calls for work from welders and metal workers that has nothing in common with that which is required from copper braziers.

Since the technique is not identical for each alloy used, measures would be taken to avoid confusion in the minds of the personnel.

With these reservations, one could predict that the introduction of the alloys and the new processes would bring a new lease of life to the light metal industry, to the very great advantages of the aerial navigation of to-morrow.

At the conclusion of the paper, the author illustrated it by means of some slides, which showed methods of assembly by riveting.

He pointed out the precautions taken to avoid corrosion and underlined the importance of the care to be taken in the manipulation and the various treatments of light alloy sheet.

He showed some illustrations obtained by means of the colorimetric test, such as is described in " Norme Air," 1063, of 6th December, 1933.*

His remarks on the colour slides were interpreted by Mr. R. Hadekel, Graduate.

The first of the coloured photographs showed a piece of light alloy sheet which had been subjected to scratching by a steel point and then to a colour test.

Where the metal had been scratched a red stain appeared, indicating an acid *pH*, whilst on the unharmed surface the *pH* is clearly basic (Fig. 1). On the same photograph can be seen the effect of hammering. The hammered part has become anodic compared to the rest of the plate.

Another slide illustrated a piece of sheet which had been folded and opened out again. In the picture the sheet reddened at the parts where there was a possibility of corrosion (Fig. 2).

A picture of a piece of duralumin which had been subjected to heat treatment at 350°C. showed red spots indicating the places at which corrosion was apt to begin (Fig. 3).

In a picture of a piece of sheet which had been subjected to quenching, the red areas, indicating where corrosion might occur, were greater than the areas in the previous sheet which had been subjected only to heat treatment (Fig. 4).

* Translation of Norme Air 1063 appears on page 308.

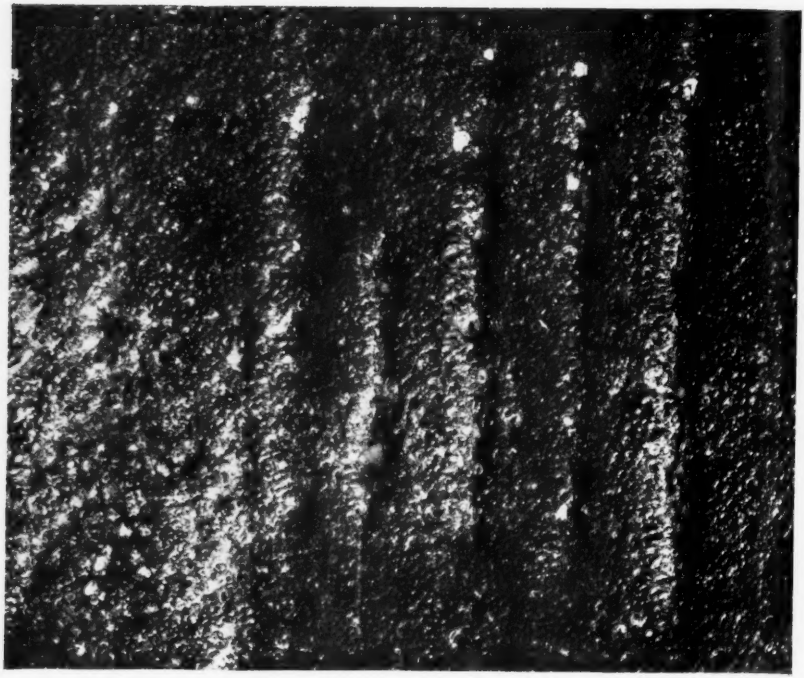

FIG. 1.—Left : Effect of cold hammering. Right : Scratches made with a steel point.

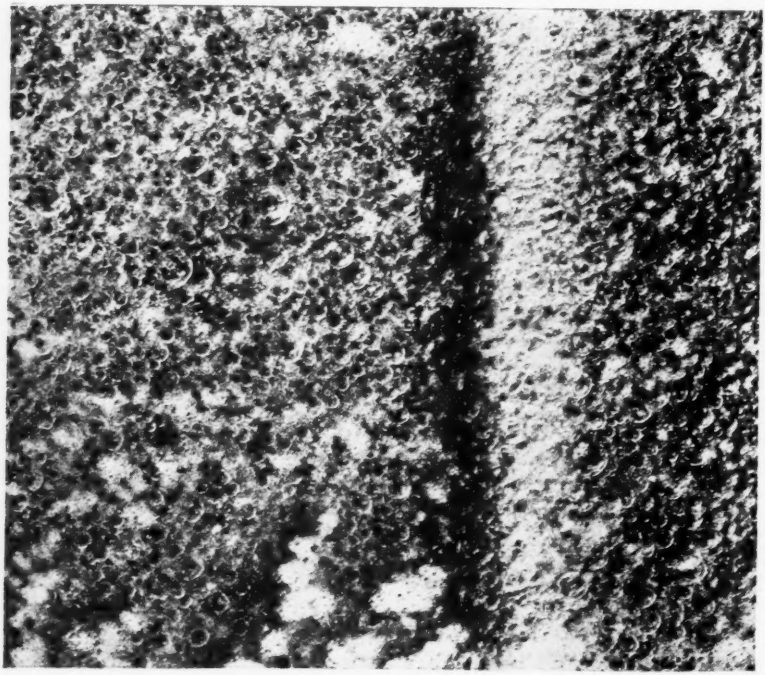

FIG. 2.—Duralumin sheet bent in the middle and then straightened.

FIG. 3.—Duralumin sheet after heat treatment.

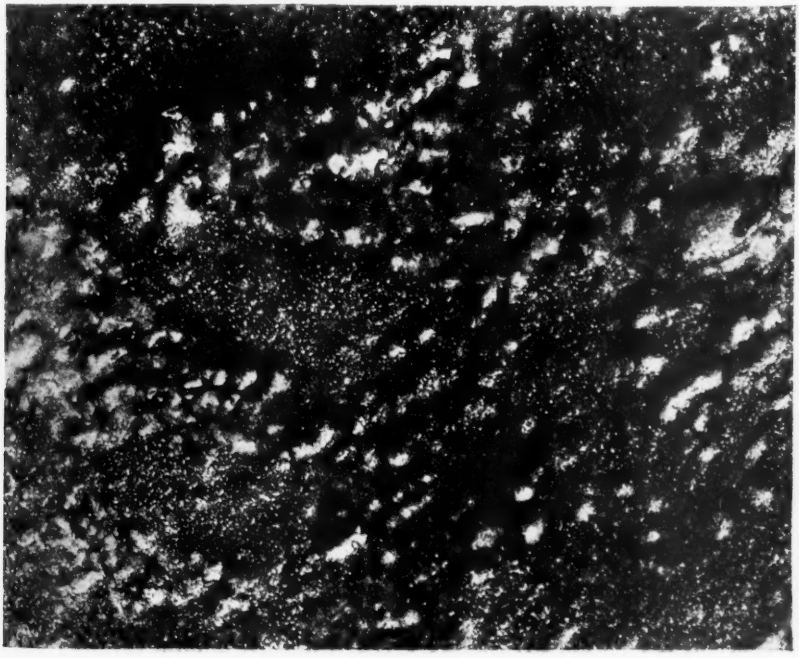

FIG. 4.—Duralumin sheet after quenching.

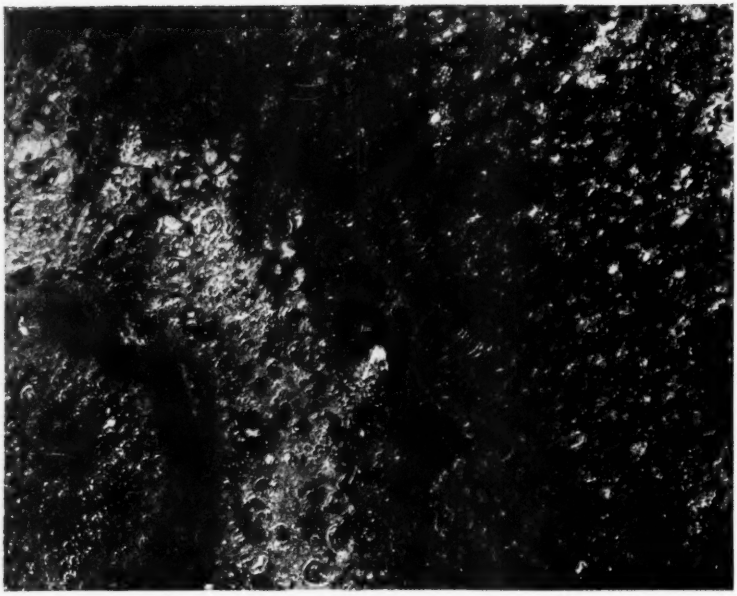

FIG. 5. Duralumin sheet showing where blow-pipe has passed over.

FIG. 6.—Duralumin sheet showing different effect of blow-pipe to that in Fig. 5.

The effect of welding on the corrosion-resisting properties of alloys was also illustrated. A blow-pipe had been passed over a sheet, and the crack produced was shown in red (Fig. 5). A further picture, however, which also related to a piece of sheet over which a blow-pipe had been passed, demonstrated that by adopting the proper conditions, welding could be carried out without altering the homogeneity of the material and without giving rise to corrosion (Fig. 6).

## Discussion.

The Chairman: He thanked the author for his most excellent paper. In one respect he was disappointed because it had rather whetted his appetite, and he felt that he wanted more. The paper seemed to infer that the author had overcome many of the problems that were still troubling them, and he would have liked to have seen a reference to some of the actual methods adopted to secure the results which the paper had inferred were obtainable.

Discussing the aluminium-magnesium alloys, for which he had a profound respect, he said that they had not yet entirely overcome their difficulties. Due to the precipitation effect of the magnesium content at certain temperatures, difficulties arose when heat treating and welding the alloys, and he wondered whether those difficulties had been overcome in France.

He believed the magnesium-cerium alloys were developed and that much work had been done in connection with them at the National Physical Laboratory. In his opinion they had a big future before them; but they were very sensitive to the effects of working, and he would welcome information as to the work which was being done with regard to them in France.

The references made in the paper to the standardisation of light alloys had impressed him. It was obvious from the paper that standardisation could be carried to excess, and probably it was being carried to excess both in France and in this country. It seemed to him that they had not yet reached the stage at which the aircraft engineer was getting all that he could use, and excessive standardisation might well hold up future development.

Dr. C. H. Desch, F.R.S.: The matters dealt with in the paper were extraordinarily interesting to scientific metallurgists as well as to those concerned with production. He agreed entirely with the Chairman that they had by no means realised the full possibilities of the alloys, and that much remained to be discovered concerning the means of utilising their properties to the best extent.

Discussing the magnesium-rich ultra light alloys, he said that the behaviour of a hexagonal metal such as magnesium was so different from that of a cubic metal such as aluminium when subjected to any kind of deformation that the processes of forging and of working them differed markedly. Consequently, experience gained in working aluminium alloys could not be applied directly to magnesium alloys, but the possibility of obtaining even magnesium alloys capable of cold working was in sight, and when their properties had been sufficiently developed their extreme lightness could be utilised more fully.

The problem of corrosion must be regarded in several different ways. The possibility of obtaining the light alloys with a very great inherent resistance to corrosion was limited. It was true that some aluminium alloys displayed a remarkable resistance to corrosion even by sea water, but in the magnesium alloys that position had not yet been attained; therefore, it would seem that research should be directed mainly to the production of protective films of greater stability than those obtained by the ordinary methods, for that seemed to be the principal direction in which progress could be made. In that connection Dr. Desch suggested that they should not too hastily condemn certain alloys which showed rather poor resistance to corrosion when tested in a salt spray, for example, if at the same time they possessed very good mechanical properties. By perfecting the methods of protection it might be possible to prevent corrosive attack on them, so that their properties could be fully utilised.

Dr. Desch joined with the Chairman in asking for a little more information concerning the aluminium alloys containing 7 and 9 or so per cent. of magnesium. They were used on the Continent to a far greater extent than in this country, and in view of their very remarkable properties it was essential that they should make a fuller study of them. Having seen some of the work done on them in Germany, he had gathered that many of the difficulties had actually been overcome, and that the inherent strength and excellent mechanical properties of the alloys could be used, in spite of the precipitation, which laboratory tests had shown to occur, which caused a deterioration of properties. Very likely there was much more information in existence than was generally available on the proper treatment of those alloys, which, in some places, were very much preferred to the alloys of the duralumin class. Discussion by those concerned with the actual manipulation and use of the alloys would be valuable.

In conclusion, he said he had been very greatly interested in the paper. It was possible to obtain better properties than were obtainable at present in certain groups of the alloys discussed, and particularly with regard to their behaviour at high temperatures there were possibilities even yet of considerable improvement.

Dr. H. Sutton (Royal Aircraft Establishment, *Fellow*): They in this country, and especially in the aircraft industry, had not realised fully the potentialities of the magnesium-aluminium series of alloys. It was interesting to appreciate, however, that those alloys had been used in this country to a very large extent in road transport engineering; he believed they had been used in very considerable quantities, for example, in motor bus construction. The reason why they had not been used to a greater extent in the aircraft industry was a little difficult to find. He believed one of the early impressions gained by aircraft constructors in regard to those particular alloys was that the limiting radius of bending was rather larger than was convenient for a good many of the pieces which had to be made. That objection, however, might not be so vital to-day as it was then, and he felt, with Dr. Desch, that more attention should be given to alloys in that class. He asked whether Mons. Le Coeuvre had had experience of their behaviour under stress in corrosion. Nowadays there was a tendency for stresses to remain locked up in a structure and for failure to occur, not necessarily under working stresses due to the aircraft, but to the way in which it had been put together. It was important, therefore, to use materials which had considerable resistance to stress under corrosion conditions, even though the applied load on the members of the aircraft were reasonably small.

An interesting possibility, it would seem, was the further use of those materials for coatings on high-strength alloys, and he asked if the author had had experience of coatings of the magnesium-aluminium alloys on materials of the high-strength duralumin type. He believed such products had been made, and they would appear to be very useful indeed.

In congratulating the French investigators on their work on that series of alloys, he said they appeared to have brought the possibilities of heat treatment to the front; the possibility of the improvement of the alloys by heat treatment in the wrought condition was largely due, he believed, to their work.

Discussing contacts between dis-similar metals, he said that recent experience with magnesium-rich alloys had shown that the avoidance as far as possible of contacts of those materials with heavy metals, at any rate, was very desirable, and that where such contacts could not be avoided it was desirable to take special precautions to protect the joints. In this country it was being found that an oil base varnish containing chromates was very valuable in affording protection of the joints between light and heavy metals.

Commenting on the author's pictures of the colour test for detecting areas in which corrosion was likely to occur, he said there was definitely a new field open to laboratory workers in that direction and they were grateful to their French friends for having brought that method forward. Perhaps the method should be used with caution, however, because not only did the distribution of corrosion

matter, but the extent of the corrosion also mattered. He believed the method would be of real service to those who had to study the constitution of alloys from the point of view of producing alloys which did not corrode, or which corroded less than those at present available.

The suggestion contained in the paper concerning film formation in corrosion fatigue was very interesting, and was rather borne out by an experience of Mr. Gerard and himself in investigating the corrosion fatigue of duralumin, about which they had presented a paper to the Institute of Metals.* They had found that the conditions of the test had affected very much the behaviour of anodically treated material. The anodic film had improved the fatigue properties in air, where presumably the re-building of the film could easily take place; but under conditions of wetting with sea water the anodic film alone had failed to give substantial protection.

Major WYLIE: With reference to production problems, and the author's apparent preference for welding as against riveting, he pointed out that the welding of light alloys had not helped production very much in this country so far. The only machines which could be adapted to welding light alloys were machines to which the work must be taken, and, therefore, they could be used only for sub-assemblies. A welding machine to which a current of 30,000 amps. had to be applied could not be so handy as a vacuum cleaner! It was not easy to appreciate complete assembly by such a machine, for which a copper cable of about 4-in. diameter was necessary and where one almost required a block and tackle to pull it about. After all, riveting was not so very bad a process. There were portable riveting machines available which would rivet at the rate of about 25 per minute, but there were very few welding machines which would weld at that rate; welding machines must be improved considerably before they would be as fast as present-day riveting machines.

The paper contained much subject matter which was of use to manufacturers of light alloys, and certainly aircraft producers would very much welcome light alloys having the physical properties of duralumin, but which did not require heat treatment. The Mg. range of materials, as they were called in this country, had not been very popular for the reasons already stated; they work-hardened too quickly, and, therefore, were unreliable. Also, they were not very reliable after welding. The paper held out prospects of great improvements in light alloys which the aircraft industry would welcome, and the improvements to be expected were set out very clearly in the paper.

Mr. A. J. MURPHY: In a paper which covered so large a territory it could not be expected that the author would have been able to go into great detail on any particular section of the subject. Each of them regarded the field covered from a different point of view, and when he had received the paper he had looked for some references to magnesium castings, which were of great interest to many. The author had taken it for granted that in air frame construction future development was almost certain to be in the direction of the increased use of strip and sheet, and presumably extruded sections. Many people at present, however, faced with very special problems of production, were turning their minds to the possibility of making use of the heat treated magnesium alloys in stressed members of the air frame and in control members. Considerable progress had been made in this direction in this country. It was not difficult to appreciate the very great advantages in production resulting from the introduction of the use of castings. He would agree that different methods of inspection must be applied, and known methods of inspection must be applied in different ways. In this connection they were witnessing some very interesting and rapid developments in the radiological method of examination of castings.

Referring to the very beautiful coloured slides with which the author had illustrated the corrosion test, Mr. Murphy said he had not clearly understood what was the nature of the solution employed. An extremely sensitive test of this

* Journal of Institute of Metals, Vol. 56, 1935, pp. 29-53.

description could be misleading if it involved more severe local corrosion than might be expected in service. He had in mind experience where corrosion and stress-corrosion tests on a laboratory scale would have led one to reject out of hand materials which, in fact, had given satisfactory service for long periods, even in the severely corrosive conditions encountered in sea planes.

He had understood the author to say that a Duralumin weld which had been quenched was less resistant to corrosion than one which had been annealed at 350°C., and presumably slowly cooled. Although he was not very intimately acquainted with the problems of welding Duralumin sheet, he had understood it to be established that materials of the Duralumin type in the solution-treated condition or the solution-treated and aged condition, were definitely more resistant to corrosion than when cooled relatively slowly from temperatures above 300°C.

There were many who would welcome an expression of opinion from the author on the use of steel and copper alloy inserts in light alloy castings. Did the author consider that special methods to guard against galvanic action—corrosion between dissimilar metals—were necessary when, for example, a bush of steel was located in an aluminium or magnesium casting by pouring the light alloy around it.

Mr. N. L. Le Brocq: With reference to the incidence of corrosion at points of contact between magnesium alloys and iron, he said he had found that in the presence of sea-water the corrosion was very marked indeed.

With regard to the point that where the alloys had been bent in treatment there was variation in the degree of corrosion as between one side of the sheet and the other, he said he had found that A.M. 503 magnesium alloy sheet was very much corroded near the worked surface, *i.e.*, the cut edge; the edge itself was not corroded, but in the immediate vicinity of the edge there was considerable corrosion. Similarly, if a sheet were stamped with numbers, the numbers would stand out quite clearly after the corrosion test. It seemed curious that the amount of cold work applied in that case rather tended to protect the material. Therefore, in regard to the sheets mentioned by the author, he asked whether the greatest corrosion occurred on the side to which the most or the least work was applied.

Mr. A. Powis Bale, A.M.I.Mech E.: With reference to certain aluminium-magnesium light alloys being non-corrosive in sea-water, he said that his own experience did not bear out the author's statement, which seemed to him to be altogether too sweeping. He wondered whether the translator had rather taken liberties with the original French; but in any case, he would like details with regard to those alloys being non-corrosive in sea-water conditions.

Mr. J. Aherne-Heron: Referring to the distortion produced in alloy sheets when welded to forms of various thicknesses, he pointed out that if electric welding overcame that stress, heat-treatment was necessary to ensure the high strength value in the material, and that in itself would cause distortion in large sheets. He asked if that would not rather detract from the value of that method of construction, because it did not seem possible to get any degree of accuracy on the welded material.

Atomic hydrogen welding had been tried out on alloys in France, and he asked the author whether the parts so welded were acceptable or whether they were condemned.

He remarked that the lecturer had dealt mostly with the light alloys in the air frame, and seemed to have a distinct bias for built-up and welded fittings. As France has always been the home and the strongest advocate of welded alloys it seemed only fair that the finished product, viz., the aeroplane, should be compared with those, of say, America's, in which fittings are comprised mostly of pressings, drop forgings and stampings. He said that they are told that little or no welding is used on American aircraft, and as they are always having it rubbed into them of the superiority of the American aircraft, it would seem that the American practice should be the last word.

Finally, he expressed disappointment that the author had said little of the enormous strides made in stamping, forging and pressing in the construction of

the modern aero engine, because it was only the modern work in stamping, forging and pressing that had made the strides possible.

## Reply to the Discussion.

Mons. Le Coeuvre replied in French to some of the points raised, and his remarks were interpreted by Mr. Hadekel.

With regard to the magnesium-aluminium alloys, which were still being discussed very much in France from the point of view of corrosion and fatigue, and also stress corrosion, he said that some of the alloys that had been tried had been frankly disappointing. On the other hand, good progress was being made particularly with a new type of alloy which had been subjected to extensive fatigue tests, using a cantilever test piece and the fatigue strength of that alloy was shown by those tests to be superior to that of duralumin.

Extensive research was being conducted into spot welding, and he illustrated a test piece, for applying static and fatigue stresses in the testing of spot-welded parts.

Corrosion fatigue, and stress corrosion in particular, were not peculiar to magnesium-aluminium alloys or light alloys only, but occurred also in stainless steel and other metals also. In his view the solution was to endeavour to arrange the constituents of the metal so that if the protective film were broken at each reversal of stress, it would re-form very quickly.

Mons. Le Coeuvre added the following to his spoken reply:—

(1) A careful study of the precipitation of the $\beta$ constituent in aluminium-magnesium alloys has been made in France by M. Lacombe at the Chemical Institute at Lille.*

In alloys containing 6.5 per cent. magnesium, the $\beta$ constituent precipitates at 300°C.

In alloys containing 8 per cent. magnesium this precipitation takes place at 350°C.

Artificial age-hardening for 20 hours at 200°C. hardens alloys containing 8 per cent. and 9.5 per cent. magnesium, and their strength is greatly improved (U.T.S. = 27.3 tons/sq.inch). But it is true to say that this advantage is only acquired at the expense of ductility.

Further, as the Chairman, Mr. Devereux, remarked, precautions have to be taken during the actual course of heat treatment with certain of these alloys: For alloys containing 8 per cent. of magnesium a fragile zone exists between 350°C. and 150°C. A prolonged period within this temperature zone must, therefore, be avoided.

(2) The reaction to sea water of aluminium-magnesium alloys has been thoroughly discussed in France. Certain types of alloy have reacted very badly to sea water, and at first gave misleading results. The experiments of Mr. A. Powis Bale were doubtless carried out on such alloys. Later, however, improvements in manufacture were achieved, so that to-day, generally speaking, the ordinary industrial products, particularly alloys containing 6 per cent. magnesium possess a marked superiority from the point of view of resistance to corrosion over high resistance alloys containing copper. This superiority is due to the nature and particular properties of the film of oxide which forms on the surface.

One must naturally guard against generalisation. The corrosion by sea water of certain aluminium-magnesium alloys could be caused by lack of care in manufacture, by an insufficient degree of purity in the basic elements used, etc., etc.

(3) *The Use of Magnesium-rich Alloys.*—The work pursued at the National Physical Laboratory by Dr. Desch is followed in France with the greatest interest. The improvement in hardness at high temperatures of magnesium alloys by the addition of cerium has been recognised. Brinell hardness numbers of from 30 to 35 at 300°C. with magnesium-nickel-cerium alloys are particularly remarkable.

* P. Lacombe—Metaux et Corrosion—12 (1937), p. 131.

In France it has not yet been possible to make forgings in magnesium alloys industrially. M. Le Coeuvre realises that from the point of view of forgeability magnesium alloys differ from aluminium alloys. The crystalline structure being different, as well as their readiness to deform, it is necessary to use tools specially adapted to each type of alloy. Research carried out in France by MM. Portevin, Prétet and Lacombe enables us to forsee the future use of these alloys in the forged state in view of the results of their laboratory tests. In the meantime certain magnesium-rich alloys can be cold-drawn and hot or cold-rolled. At the present time petrol tanks are being made in magnesium-rich alloys. Welding the sheets is a comparatively simple process.

(4) *Resistance to Corrosion of Magnesium-rich Alloys.*—The mechanics of sea water corrosion of magnesium-rich alloys is not the same as in the case of aluminium-rich alloys. In the first case the action is to a very large degree purely chemical, while in the second electro-chemical action is the predominant cause.

As Dr. Desch said, it seems that research should be concentrated towards forming stable surface films. Some important work on electro-chemical protection of magnesium alloys has been carried out in France by M. Pomey at the Renault Establishment. The films obtained are no longer films made up of merely magnesium oxides, but are complex films of alkaline magnesium fluorides and oxides. The films formed are impermeable, and are a remarkably efficient protection.

As far as corrosion fatigue tests of magnesium-rich alloys are concerned, there have been as yet no systematic tests on test pieces protected by the electro-chemical method. It will be most interesting to extend to anodically protected magnesium alloys the experiments carried out by Dr. Sutton on anodically protected aluminium alloys, and to study the conditions in which the protective film breaks up and reforms in air and in the salt spray.

When tested under corrosive conditions it is seen that magnesium alloys give way very suddenly at the fatigue limit, as is the case with all metals, but it is absolutely certain that with suitable protection magnesium alloys behave remarkably well under corrosion fatigue tests. The remarkable work of Dr. Sutton on the resistance to corrosion fatigue of protected light alloys has shown that in the presence of a corrosive reagent such as the salt spray, a well protected test piece behaves as well as a test piece fatigue tested *in vacuo*. Identical results have been obtained in France at the laboratories of the technical experimental establishment at Issy les Moulineaux by M. Cazaud. The figures obtained for the fatigue strength of magnesium alloys are already most satisfactory. But as both Dr. Desch and Dr. Sutton remarked, the magnesium-rich alloys have much important headway to make up (1) in comparison of fatigue strength, (2) in comparison of strength at high temperatures, (3) in comparison of resistance to corrosion by sea water.

The use of magnesium alloys for coatings on aluminium alloys has hitherto been discarded because of the sensitivity of magnesium alloys to chemical attack by reagents. It did not appear that there would be any great difficulties in the use of " hot spraying " (Schoop process), but the alloy should be able to be wire-drawn economically.

It should also be possible to manufacture alloys of the Alclad or Védal types, substituting magnesium for aluminium as the surface element. Magnesium being much less noble than the high resistance aluminium alloy, a protection could certainly be assured to the latter. Besides, this is the principle of the protective action which takes place giving aluminium-magnesium alloys containing 6 per cent. magnesium such good anti-corrosion properties in sea water.

Finally, the application of a magnesium protection surface to aluminium light alloys should be a relatively easy task. In France research conducted by M. Cournot* led to magnesium being discarded on account of the doubt which

* Mémoires de la Commission Français e de Corrosion (Receuil des Memoires de 1926-27, p. 147).

existed concerning its efficacy as a protective surface. More accurate information, since acquired, on the nature of protective films, which form spontaneously on the surface of aluminium-magnesium alloys, allow new possibilities to be foreseen. Research along these lines may prove to be of great benefit.

(5) *Use of Welding Machines.*—Electric welding machines for spot or seam welding in present use in aeronautical construction are mainly fixed machines. Consequently they do not contribute much to efficiency in production, which would be improved by the use of mobile welding units. The problem has been solved in the welding of steels. The diameter of the electric cables does not exceed one inch. Theoretically, as Major Wylie pointed out, they should be of 4 inches diameter, but the time during which the 30,000 ampère current flows is very short, so that a cable of even one inch diameter does not become hot. There is still considerable room for improvement in welding machines, and efforts towards this end should be encouraged.

Riveting machines have been tremendously improved during recent months, and have thus contributed much to efficiency of production.

(6) *Use of Steel or Brass Inserts in Certain Light Alloy Castings.*—The practice of using inserts in a light alloy casting by pouring the light alloy under pressure round the insert, as mentioned by Mr. Murphy, is very convenient. It reduces costs, simplifies manufacture, and contributes to the speeding up of production. Danger does arise from the point of view of corrosion if the joint is allowed to come in contact with an electrolyte. By taking certain precautions this contact can be avoided. There are cases where certain mixed assemblies of this nature do not give rise to electrolytic action. M. Canac recently gave out that certain aluminium-magnesium alloys, assembled in contact with steel sheet, behaved remarkably well in the sea at Toulon, without any surface protection. This phenomenon has already been observed several times, and the engineer will in future have to choose his materials judiciously in order to make up combinations so that local couples are polarised almost as soon as they are formed.

(7) *The Effect of Cold Hammering on the Resistance to Corrosion of Light Alloys.*—It is true, as M. Le Brocq remarked, that light alloys become corroded on the worked surface, and the corrosion does not always occur on the cut edge itself, but in the immediate vicinity of this edge.

The theories advanced by Mr. Evans on local cells and differential couples set up by exposure in air partly explain these phenomena as far as light alloys are concerned.

In Fig. 1 the hammered surface is shown to be anodic. It appears in red and obviously, if placed in sea water, the sheet would be attacked in the first place on the cold hammered part.

But it is possible that with certain alloys the couple formed by the hammered part and the unhammered surface might be reversed, and that the cold hammered surface would not be attacked, to the detriment of the surrounding surface which becomes anodic.

Here again the colorimetric test can give useful information on the respective polarity of the unhammered and the hammered surfaces and illustrate the particular properties of certain alloys.

The facts mentioned by M. Le Brocq concerning magnesium-rich alloy sheets deserve closer study. It is by no means certain that the theories applicable to aluminium alloys can be extended to magnesium alloys.

(8) *Resistance of Welds to Corrosion After Treatment.*—The question was asked whether the electric spot welding of light alloys does not create a risk of heterogeneity in the surface, which gives rise to corrosion. Quite recent experiments have been carried out at Issy les Moulineaux on this important question. They were carried out at the time on duralumin sheet and on aluminium magnesium alloy sheets containing 6.5 and 8 per cent. magnesium. The facts were recorded by colorimetric tests (" Norme Air " 1063). (This test is a means of studying effects, and not a method of inspection for eliminating certain products.)

When the intensity of the current was correct, the surface structure of the metal remained unaltered, and no heterogeneity appeared. When, however, a spot weld was made purposely in such a manner as to alter the surface structure, the heterogeneity was shown up clearly by a red patch.

Seam welding, carried out under the came conditions, showed a complete absence of heterogeneity in aluminium-magnesium alloys containing 6 per cent. magnesium. On the other hand, a slight heterogeneity was found at the start of the seam on two other high resistance alloys. Special precautions therefore have to be taken with these alloys when starting the operation of the machine.

Heat treatment after welding is thus also necessary with certain alloys.

Heat treatment after welding, as Mr. J. Aherne-Heron remarked, gives rise to a risk of deformation, and may lead to inaccuracy in the assembly. That is why constructors tend to favour alloys which require no special heat treatment after welding, and an advantage can be foreseen on that account in the use of aluminium-magnesium alloys.

Atomic hydrogen welding, regarding distortion, would be less advantageous than spot welding, on account of the heating up of the zone in the neighbourhood of the weld.

(9) *Standardisation of Light and Ultra-Light Alloys.*—Standardisation could be conveniently carried out from now by experimental methods. That need not hold up future progress of production. Above all experimental methods agree very well with the results of practical research.

Well defined experimental tests often assist progress and become a productive instrument in the hands of research workers.

At a time when quantity production is being intensified, a minimum standardisation is necessary to ensure interchangeability and regularity of manufacture.

Bearing this in mind, it must be recognised, as the Chairman (Mr. Devereux) remarked, that the evolution of the science of aeronautics is proceeding so rapidly that excessive standardisation can only lead to confusion, and become a hindrance rather than a stimulus in research development.

A French proverb says:—" In all things excess is a fault."

Air 1063.

MINISTERE DE L'AIR.

STUDY OF HETEROGENEITY IN METALS AND ALLOYS BY MEANS OF COLOUR INDICATIONS.

*Use of the Method.*

The coloriscopic method is a process of microscopic examination, the most general use of which is for the inspection of metals or alloys, in the raw or finished state; notably it can be used for the inspection of the homogeneity of sheet and sections, the successful accomplishment of riveting and welding, anti-corrosive qualities, the continuity of surface protection, etc.

*Principle.*

The process consists of bringing to light the heterogeneities in the metal or alloy by the use of a colour indication of *pH* (*pH* expresses the degree of acidity or alkalinity of the medium, that is to say, the concentration of hydrogen ions).

*Method of Operation.*

The test pieces, parts or assemblies are prepared in accordance with Air 0753. By means of a compressed air spray gun, three coats of a solution of 100 grammes of pure gelatine per litre of the reagent used (see " Norme Air " 0754) are applied. The second and third coats are applied as soon as the preceding coat has taken.

After the reagent has been allowed to attack the metal for several hours, a colouring matter of standard *pH* is sprayed on the surface. This is prepared from the following formula :—

| | |
|---|---|
| Methyl orange ... ... ... | 0 gr. 1 |
| Methyl red ... ... ... | 0 gr. 4 |
| Bromothymol blue ... ... | 0 gr. 4 |
| Naphtholphthalene ... ... | 0 gr. 32 |
| Phenolphthalene ... ... | 0 gr. 5 |
| Cresolphthalene ... ... ... | 1 gr. 6 |

To be dissolved in 100 grammes of alcohol at 70°C.

The surface to be examined can also be coloured by applying with a soft brush the gelatinous solution, to which has been added the colouring agent specified above (to the order of 5 per cent.).

The colour reactions which appear correspond to the following values of *pH*, expressed in Sorensen units (cologarithm, to base 10, of the concentration of hydrogen ions).

| | | | | | |
|---|---|---|---|---|---|
| Acids | Red ... ... | *pH* = 3 | Bases | Green ... ... | *pH* = 8 |
| | Orange-yellow ... | *pH* = 5 | | Green-blue ... | *pH* = 9 |
| | Yellow ... ... | *pH* = 6.5 | | Violet ... ... | *pH* = 11 |
| | | | | Red-violet ... ... | *pH* = 12 |

After it is dry, the part can be handled without precaution. The colours remain unaltered for several months (three at least). Washing in hot water removes the coloured gelatine film from the part, so that it can be used.

*Reproduction.*

It is possible to reproduce the colours by using autochrome plates and trichrome (three-colour process) prints.

A cheaper method is to photograph and print the colours obtained in black and white through a red screen, using panchromatic plates; the red zones thus appear in white on the finished print.

*6th December*, 1933.

The CHAIRMAN: He proposed a hearty vote of thanks to Mons. Le Coeuvre for his paper, which the meeting had enjoyed; and to Mr. Hadekel, who had so ably translated.

(The vote of thanks was accorded with acclamation and the meeting closed.)

# ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

*Issued by the*
*Directorates of Scientific Research and Technical Development, Air Ministry.*
*(Prepared by R.T.P.)*

No. 65. MARCH, 1939.

*Insufficient Training of Russian Pilots.* (Les Ailes, No. 901, 22/9/38, p. 6.) 65/1 France.)

According to the author of " Russian Aviation "* a large number of Russian pilots can scarcely be considered as trained in the European sense. This has now been realised by the Russian authorities, since, by a recent decision of Marshal Vorochilov, the examination for pilot's certificate has been made more difficult and the members of the committees who are in charge of flying instruction have been rendered personally responsible for the quality of the flying training of each pilot leaving the school.

*The Military and Political Considerations which Led to the Choice of the Flying Boat for British Empire Communications.* (H. Lufft, Luftwehr, Vol. 5, No. 8, Aug., 1938, p. 313.) (65/2 Great Britain.)

The choice of the flying boat instead of the land plane appears to be mainly due to the following factors:—

(1) Land aerodromes are difficult to defend against attack, especially sabotage by natives. A harbour is easily patrolled by ships.

(2) The landing surface on the ground may be affected by weather or enemy action. This does not apply to landing on a water surface.

(3) Overland routes require a considerable ground organisation which is not only expensive but also vulnerable to enemy action. For this reason the Cape-Cairo route has now been shifted from the direct central African position to the east coast.

It appears that the object throughout has been to link the command of the sea by surface ships to the problem of Empire communication by air.

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* L'Aviation Sovietigne, published by Les Ailes-Paris, 12 frcs.
*Principal Contents*:
1. Equipment of the Air Force.
2. Technical Development.
3. Industrial Organisation.
4. Personnel.
5. Civil Aviation.
6. Sporting Aviation.
7. Parachutism.
8. Politics and Aviation.

According to the anonymous author, Russian aviation suffers from the low mental standard of the rank and file and from the political interference with those occupying the higher grades. Thus both the single-seater fighters I 5 and I 15 were designed whilst their originators were in prison!

*Bombing Aviation (Résumé of Rougeron's Theories).* (E. Margis, Luftwehr, Vol. 5, No. 8, August, 1938, pp. 314-318.) (65/3 Germany.)

Rougeron's theories on bombing have been studied with interest by the experts of all nations. In Vol. I the author considers the development of the light fast bomber in contradistinction to the " Flying Fortress " of Douhet. In the Vol. II. new methods of bombing attack are discussed, of special interest being the use of planing bombs against a fleet at anchor. According to Rougeron, " The days of the fleet are numbered," and the British fleet could be destroyed in a few hours should it be foolhardy enough to seek shelter in Gibraltar harbour. Speaking generally, Rougeron is obsessed with the importance of speed in aircraft. According to him, an advantage in speed will always make up for lighter armament. In air fighting, a number of high speed craft fitted with light guns will get the better of a smaller number of slower but heavier armed machines. As regards anti-aircraft artillery, Rougeron adopts Fisher's famous maxim concerning the armament of the dreadnought class of ship: " The biggest gun and the smallest gun." Only by utilising automatic guns up to 8in. calibre can the ground defence hope to keep aircraft raiders at bay.

NOTE.—For an abridged translation of Rougeron's book see R.A.F. Quarterly, October, 1938, and January, 1939.

*Can England Maintain its Oil Supply in War?* (P. Ruprecht, W.T.M., Vol. 42, No. 10, October, 1938, pp. 453-6.) (65/4 Germany.)

The production of synthetic fuel from coal in England has been investigated by the Falmouth Committee and turned down in favour of extensive oil storage and tanker fleets.

According to the report, the main reason for the decision is an economic one, the synthetic fuel requiring a considerable outlay in plant and subsidy.

Now cost is relative and there is no guarantee that the same economic consideration would apply in war.

Britain's peace time consumption amounts to 12.6 million tons. In 1936 the whole of Europe consumed $43 \times 10^6$ tons, U.S.A. $186 \times 10^6$ tons, whilst the world production amounted to $247 \times 10^6$ and increased to only $278 \times 10^6$ tons in 1937.

It is obvious that a war in which several countries participate will cause a fierce competition for oil supplies and the cost may well rise to a figure commensurable with that of the synthetic fuel. It thus appears that apart from the official reasons given in the report, the Falmouth Committee were of the opinion that:—

(*a*) A future war will be short, in which case the stored supplies will suffice.

(*b*) The oil fuel shortage will be felt more keenly by England's possible adversaries than by the home country.

The author questions both these conclusions, and, as an example, quotes the Japanese Navy which has been equipped to burn coal if the oil supply should fail.

*Military Uses of Television.* (W.T.M., Vol. 42, No. 10, October, 1938, pp. 472 and 473.) (65/5 U.S.A.)

According to reports from the U.S.A., a long distance range finder embodying television principles has been developed for the coast artillery. Two television cameras at the end of a base line are adjusted till the two images coincide. It is claimed that this range finder by employing wave length outside the optical range will function in total darkness or fog. The French General Neissel is also stated to be enthusiastic about the future possibilities of television for reconnaissance work. Even in its present state of development, Neissel is of the opinion that television already presents some advantages over normal wireless methods of communication.

*The Internal Ballistics of Rifled Gun Barrels with Special Reference to Frictional Effects.* (K. H. Bodlien, Z.G.S.S., Vol. 34, No. 2, February, 1939, pp. 33-38.) (65/6 Germany.)

The friction of the shell in the gun barrel is determined by a simultaneous record of the recoil of the barrel and the gas pressure in the barrel. The great difficulty is to obtain accurate co-ordination between the two sets of records.

It appears that the shell experiences two well-defined resistance maxima whilst travelling through the barrel, the second maximum being due to the rotary acceleration impressed by the rifling. The condition of the gun affects the results very considerably and further work is in progress.

An alternative method for determining the frictional effect of gun rifling has been proposed. Two equal shells are fired simultaneously in opposite directions from a central chamber fitted on either side with a rifled and plain barrel respectively.

The resultant deflection of the suspended unit gives a measure of the frictional effect. No experiments have as yet been carried out by this method.

*Aerial Rearmament in the U.S.A.—Estimated Cost of Some Aircraft Types.* (Inter Avia, No. 622, 28/2/39, pp. 1-3.) (65/7 U.S.A.)

The following estimate of dollar prices are of interest:—

| Type. | Aircraft. | Cost of power plant. | Equipment. | Total. |
|---|---|---|---|---|
| Single-engined single-seater fighter ... | 13,600 | 9,000 | 6,200 | 28,800 |
| Twin-engined single-seat fighter ... | 60,200 | 18,000 | 4,460 | 82,660 |
| Twin-engined bomber ... ... | 90,000 | 16,650 | 16,566 | 123,216 |
| Twin-engined attack plane ... ... | 76,370 | 20,000 | 5,400 | 101,770 |
| Twin-engined observation plane ... | 78,400 | 16,000 | 20,600 | 115,000 |
| Twin-engined observation amphibian | 52,750 | 10,800 | 6,900 | 70,450 |
| Single-engined transport ... ... | 41,100 | 8,000 | 8,900 | 58,000 |
| Twin-engined transport ... ... | 67,500 | 11,000 | 10,600 | 89,100 |

*The Increase in Calibre and Performance of Modern Anti-Aircraft Artillery.* (C. Rougeron, La Science et la Vie, No. 261, March, 1939, pp. 210-18.) (65/8 France.)

Modern anti-aircraft artillery must not only possess long range in order to reach high flying aircraft but the time taken by the projectile to reach this altitude must be as short as possible. For a given muzzle velocity the time of trajectory is diminished by increasing the calibre. For a given calibre an increase in muzzle velocity is of extreme benefit since it flattens the trajectory and this, by itself, reduces the trajectory time still further. Increase in calibre reduces rate of fire unless complicated mechanical loading devices are fitted. On the other hand high muzzle velocities lead to rapid wear of the gun. This wear is, however, limited to certain sections of the barrel only and if the gun is properly designed these parts can be replaced fairly easily. Till quite recently most A.A. artillery were of 75 mm. calibre. The 88 mm. and 105 mm. guns of German origin used in the Spanish war demonstrated the superiority of the larger calibre. There is no doubt that in the near future even larger calibres will be required.

*Air Defence Zone on the Western Front.* (General Kitzinger, Die Wehrmacht, Vol. 3, No. 3, Feb. 1, 1939.) (65/9 Germany.)

The object of the new Western Air Defence Zone is to prevent enemy aircraft from penetrating into the interior of Germany.

Based on long meteorological experience, the most favourable grouping of fighter squadrons has been carried out. Various calibre anti-aircraft guns, intermingled with searchlights have been placed over a considerable depth of territory, sectors of special importance being also provided with kite and balloon barrages (floating mine systems).

Reserves are housed underground in ample bomb-proof shelters fitted with all modern appliances.

Special attention is given to the signalling section, all the positions being connected by cable and wireless.

The anti-aircraft batteries are nearly all mechanised and special roads have been built to facilitate a rapid regroupment. The supply system for this zone is very elaborate, the water supply alone requiring the help of foremost German geologists.

All emplacements in the zone are protected by armour and ferro-concrete. An enemy attacking on the ground, after passing the first line, meets a whole system of defensive earth works, interconnected to a depth of 60 km. All roads can be blocked and special tank traps are provided. The whole system will force attacking aircraft to fly at such great heights that their efficiency will be seriously impaired. (Oxygen breathing, blind flying.) It is confidently thought that even if isolated aircraft should be able to pass and attack the Ruhr, the possible damage would be slight, since the crew would be fatigued and the possible bomb load would be small.

*Design and Construction of External Strongholds.* (C. F. de Steiger, J. Air Raid Protection Inst., Vol. 1, Dec., 1938, pp. 33-43. Eng. Absts., Vol. 2, No. 1, Section 1, January, 1939, p. 5.) (65/10 Great Britain.)

" Strongholds " are defined as structures designed to give the highest possible degree of protection against all types of aerial attack, and, in particular, against direct hits by high-explosive bombs. The author deals only with strongholds built independent of other structures, taking no advantage of the possible protective value of buildings above or near. He discusses the advantages of using reinforced concrete in such structures, and describes strongholds of German and Swiss design.

*Downwash at the Tail Surfaces of an Aeroplane with a Wing of an Arbitrary Plan Form.* (J. Ostoslavsky and M. Mogilevsky, C.A.H.I. Report No. 312.) (65/11 U.S.S.R.)

In 1930 the authors of the present work developed a formula for the downwash at the tail surfaces on the assumption of an elliptical distribution of the circulation along the wing span. This formula gave satisfactory results for types of wings used at that time. The use of highly tapered wings and wings with split flaps situated on a part of the wing span necessitated the introduction of a factor $x$ which is the function of the tail surface co-ordinates, the wing taper and the increase in lift due to the flap deflection.

Charts of the $x$ function (both for the case of a rectangular wing ($K=1$) and tapered wings with a taper of $K=\frac{1}{2}$ and $K=\frac{1}{3}$) are given and some practical recommendations to designers are added.

The results of these calculations are compared with experimental data obtained by Muttrey, A. Martinov and others and a practical method for the determination of the downwash at large angles of incidence is given.

At the same time an approximate analysis of the effect of the distortion of free eddies by the induction as well as the influence of the rolling up of the wake on the downwash at the tail surfaces is given. It appears that both these factors may be safely neglected in practice.

*Hydrodynamic Forces on an Accelerated Cylinder Moving in Two Dimensions.* (M. A. Omara, Phil. Mag., Vol. 27, No. 181, Feb., 1939, pp. 200-211.) 65/12 Great Britain.)

In this paper the Blasius contour integral expressions for the determination of the resultant force and moment on a profile in a Joukowski's stream are extended to the case of the general uniplanar motion of the profile.

The potential function of the fluid motion induced by the motion of the solid is given in the form of a Laurent's series, the coefficients of which are expressed in terms of the coefficients of the expansion of the function transforming conformally the exterior of the profile into the exterior of a unit circle.

The resultant force and moment are calculated in terms of these coefficients, and the application to the classical case of the ellipse gives the well-known results.

Application to the case of a flat plate is given.

*Uniform Motion of a Sphere or a Cylinder Through a Viscous Fluid.* (B. R. Seth, Phil. Mag., Vol. 27, No. 181, Feb., 1939, pp. 212-9.) (65/13 Great Britain.)

(1) Oseen's criticism of Stokes's solution that it is defective at points distant from the sphere holds good only when the liquid flows past the fixed sphere, and not when the sphere is moving uniformly through it.

(2) When a large sphere moves slowly through a slightly viscous liquid the value of the drag should be at least greater than one and a half times that given by Stokes.

(3) As $R$ increases from $O$ to $\infty$ the kinetic energy of the fluid decreases from infinity to the value for the corresponding irrotational motion.

(4) For a very large sphere or a cylinder moving slowly through a slightly viscous liquid the motion is everywhere irrotational except in a thin layer near the boundary.

*The Lift and Drag of a Rectangular Wing Spanning a Free Jet.* (H. B. Squire, Phil. Mag., Vol. 27, No. 181, Feb., 1939, pp. 229-239.) (65/14 Great Britain.)

Investigations by Glauert and Stüper lead to discordant results for the effect of the jet boundary on the lift and drag of a rectangular wing spanning a free jet of circular section. This problem is solved by an independent method; the results obtained are in agreement with Glauert's results.

*The Unsteady Lift of a Finite Wing.* (R. T. Jones, N.A.C.A. Tech. Note No. 682, Jan., 1939.) (65/15 U.S.A.)

Unsteady lift functions for wings of finite aspect ratio have been calculated by approximate methods involving corrections of the aerodynamic inertia and of the angle of the infinite wing.

The starting lift of the finite wing is found to be only slightly less than that of the infinite wing; whereas the final lift may be considerably less. The calculations indicate that the distribution of lift near the start is similar to the final distribution.

Approximate operational equivalents of the lift functions have been devised to facilitate the calculation of lift under various conditions of motion.

*Experimental Aerodynamics.* (R. Pris, Bulletin des Services Techniques, No. 83 and 83a, 1938.) (65/16 France.)

In the preface, the author states that his aim is to provide the aircraft designer with the necessary data to enable him to utilise the most recent information on the controlling factors of performance, stability and safety. The subject matter is treated on the lines of the course in aerodynamics given by Professor Toussaint at the Paris University. The explanatory matter is, however, restricted to the utmost, the main emphasis being placed on tables and diagrams. Most of these are collected in a separate Volume (83*a*).

The principal points dealt with are the following:—

(1) Wing characteristics with special reference to high lift devices.
(2) Drag of fuselage, including fittings.
(3) Drag of engine installation.
(4) Action of propeller, both at normal and oblique incidence.
(5) Stability of control.

It appears that most of the data given are based on N.A.C.A. publications, and, whilst the book may to some extent fulfil the author's hope and be of use to the designer, it is felt that the treatment will appeal rather to the general student of aerodynamics who is looking for a summarised statement on certain aspects of his science, and to whom the extensive bibliography quoted at the end of each chapter will be specially useful.

*Vaneless Diffusors.* (V. Dowshik, C.A.H.I. Report No. 305.) (65/17 U.S.S.R.)

According to the theory of Pfleiderer, the friction of the walls of a vaneless diffuser causes a gradual reduction in the angular momentum of the fluid, this reduction being effective over the whole width of the channel. As a result, the path of the fluid gradually departs from the ideal logarithmic spiral. Experiments at the C.A.H.I. have, however, shown that the effect of friction is confined to a relatively thin boundary layer and that the major part of the fluid in the centre of the channel obeys potential flow laws.

The author investigates the flow picture obtained under these conditions, paying special attention to the production of pulsation and breakaway of the flow.

As a result a new method for estimating the losses in a vaneless diffusor is given.

*Approximate Method for Determining the Hydrodynamic Forces on an Under Water Wing of Finite Span.* (A. Wladimirow, C.A.H.I. Report No. 311.) (65/18 U.S.S.R.)

The theory of the motion of a body below the free surface of an ideal heavy fluid is reviewed, with special application to a body of aerofoil shape. Theoretical expressions are next developed for the lift and wave resistance of a wing of infinite span.

The effect of viscosity and finite span are then expressed in an approximate form by the author and the final prediction compared with experiments in the C.A.H.I. tank. It is concluded that the method gives satisfactory results for small angles of incidence, provided the depth of the wing below the free surface is at least equal to one chord.

*Downwash at Tail Surface Taking into Account the Mutual Interaction of Propeller and Wing.* (E. Kolossow, C.A.H.I. Report No. 315.) (65/19 U.S.S.R.)

A theoretical expression for the downwash is obtained by calculating the effect of the propeller on the distribution of the circulation along the span of the wing.

Both the case of single and multi-engine installations is investigated and the application of the resultant formulæ is simplified by the provision of diagrams.

Finally the results are compared with those obtained from previous formulæ and also with direct experiments.

*The Vortex Resistance of Theoretical Profiles.* (A. Kosjmodemjausky, C.A.H.I. Report No. 317.) (65/20 U.S.S.R.)

The author calculates the vortex resistance of a circular cylinder for the cases of laminar, turbulent and transition flow. The problem is also solved for a series of elliptic cylinders and symmetrical profiles of the Joukousky type. The calculations require the position of minimum pressure or of separation to be known, and for this purpose the author has reviewed existing experimental data and chosen the most reliable figures. The method is based on the following additional assumptions:—

1. The width of the vortex zone behind the body is equal to the distance between the lateral points of separation.
2. The velocity of a completely formed vortex is in the same direction as that of the undisturbed flow.

In conclusion, the author shows how to calculate in certain cases the periodicity of the shed vortices. The pressure distribution between the stagnation point and the (known) point of separation can also be determined.

*A Non-Linear Wing Theory and its Application to Rectangular Wings of Small Aspect Ratio.* (W. Bollay, Z.A.M.M., Vol. 19, No. 1, Feb., 1939, pp. 21-35, in English.) (65/21 U.S.A.)

The author demonstrates that the flow round a wing of small aspect ratio is not purely a stalling phenomenon but is amenable to treatment by the perfect fluid theories. A new non-linear theory is developed which differs from previous theories (Prandtl and Blenk) in the fact that the trailing vortices are assumed to leave the wing at an angle $\theta$ which can be determined approximately by the Helmholtz vortex laws.

For the limiting case of zero aspect ratio, the normal force co-efficient

$$C_N = 2 \sin^2 \alpha$$

For infinite aspect ratio

$$C_N = 2\pi \sin \alpha \cos \alpha$$

in agreement with the Prandtl lifting line theory. For intermediate aspect ratios, the theory gives the transition between the two limiting cases, the agreement with experiment being very good for very small aspect ratios and fair for larger ones.

*Pressure Distribution Measurements on a Tapered Wing with a Full Span Split Flap in Curved Flight.* (T. Troller and F. Rokus, N.A.C.A. Tech. Note No. 683, Jan., 1939.) (65/22 U.S.A.)

Pressure-distribution tests were made on the 32-foot whirling arm of the Daniel Guggenheim Airship Institute of a tapered wing to determine the rolling and yawing moments due to an angular velocity in yaw. The model was tested at 0° and 5° pitch, −1° and 5° yaw, and with a full-span flap deflected 60°. The results are given in the form of span load distributions and in calculated moment coefficients.

CONCLUSIONS.

1. The rolling-moment coefficients measured at the whirling arm are in fairly close agreement with those derived by means of a simple approximate theory even for high deflection of the full-span flap.

2. The rolling moments are little affected by the angle of yaw within the range of the tests.

3. The ratio $L/L_w b$ decreases with the lowering of the flap by about 16 per cent. for the 0° pitch setting of the wing and is almost constant at 5° pitch.

4. The ratio $N/Db$ decreases with the lowering of the flap.

*A Flight Comparison of Conventional Ailerons on a Rectangular Wing and of Conventional and Floating Wing Tip Ailerons on a Tapered Wing.* (H. A. Soule and W. Gracey, N.A.C.A. Report, 1938.) (65/23 U.S.A.)

Flight tests comparing the relative effectiveness of conventional ailerons of the same size on wings of rectangular and tapered plan forms were made with a Fairchild 22 aeroplane. Information is included comparing conventional and floating wing-tip ailerons on a tapered wing. The results showed that the conventional ailerons were somewhat more effective on the tapered than on the rectangular wing. The difference, however, was so small as to be imperceptible to the pilots. The floating wing-tip ailerons were only half as effective as the conventional ailerons, and, for this reason, were considered unsatisfactory.

*The Effect of Compressibility on Eight Full-Scale Propellers Operating in the Take-off and Climbing Range.* (D. Biermann and E. P. Hartman, N.A.C.A. Report No. 630, 1938.) (65/24 U.S.A.)

Tests were made of eight full-scale propellers of different shape at various tip speeds up to about 1,000 feet per second. The range of blade-angle settings investigated was from 10° to 30° at the 0.75 radius.

The results indicate that a loss in propulsive efficiency occurred at tip speeds from 0.5 to 0.7 the velocity of sound for the take-off and climbing conditions. As the tip speed increased beyond these critical values, the loss rapidly increased and amounted, in some instances, to more than 20 per cent. of the thrust power for tip-speed values of 0.8 the speed of sound. In general, as the blade-angle setting was increased, the loss started to occur at lower tip speeds. The maximum loss for a given tip speed occurred at a blade-angle setting of about 20° for the take-off and 25° for the climbing condition.

The compressibility loss at the take-off for controllable propellers was considerably reduced because of decreased blade-angle operation necessitated by increased power coefficients, but the reverse was true for fixed-pitch propellers inasmuch as the higher power coefficients resulted in reduced engine speeds.

A simplified method for correcting propellers for the effect of compressibility is given in an appendix.

*Tests of Five Full-Scale Propellers in the Presence of a Radial and a Liquid-Cooled Engine Nacelle, including Tests on Two Spinners.* (D. Biermann and E. P. Hartman, N.A.C.A. Report No. 642, 1938.) (65/25 U.S.A.)

Wind-tunnel tests are reported of five 3-blade 10-foot propellers operating in front of a radial and a liquid-cooled engine nacelle. The range of blade angles investigated extended from 15° to 45°. Two spinners were tested in conjunction with the liquid-cooled engine nacelle. Comparisons are made between propellers having different blade-shank shapes, blades of different thickness, and different aerofoil sections.

The results show that propellers operating in front of the liquid-cooled engine nacelle had higher take-off efficiencies than when operating in front of the radial engine nacelle; the peak efficiency was higher only when spinners were employed. One spinner increased the propulsive efficiency of the liquid-cooled unit 6 per cent. for the highest blade-angle setting investigated and less for power blade angles. The propeller having aerofoil sections extending into the hub was superior to one having round blade shanks. The thick propeller having a Clark Y section had a higher take-off efficiency than the thinner one, but its maximum efficiency was possibly lower. Of the three-blade sections tested, Clark Y, R.A.F. 6, and N.A.C.A. 2,300-34, the Clark Y was superior for the high-speed condition, but the R.A.F. 6 excelled for the take-off condition.

*A Summary of N.A.C.A. Investigations on High Lift Devices.* (C. J. Wenzinger, J.S.A.E., Vol. 44, No. 2, February, 1939, p. 28.) (65/26 U.S.A.)

Two general classes of high lift devices are considered, located at the leading and trailing edge of the wing respectively. Several combinations of both classes are also described.

The effect on the lift due to type of device, size, location on wing profile and Reynolds number are discussed and the conclusions presented in the form of charts. It appears that the slotted type of flap (in particular the N.A.C.A. double slot) is the most promising.

The increase in lift of most of the devices discussed is relatively constant over the range of Reynolds numbers. It is thus possible to select a basic aerofoil and add the desired high lift device with fair accuracy.

In the discussion, the possibility of providing boundary layer control by suction at the critical points of unstable air flow and blowing out the air at points where it would help to reduce drag was mentioned.

*Pressure Cabin Investigations (Phase I).* (J. G. Taylor, and others, A.C.I.C., Vol. 8, No. 710, 1/10/37, pp. 1-72.) (65/27 U.S.A.)

This most interesting and well illustrated report deals with the following aspects of the problem:—

1. Experimental investigations, including physiological requirements.
2. Development and process for construction and sealing all metal fuselage and compartments for supercharged high altitude aeroplanes.
3. Stress analysis of pressure cabin.
4. Some strength characteristics of laminated glass for windows of pressure cabins.
5. Automatic control of air pressure and flow in cabin.
6. Physiological requirements.
7. Air conditioning.
8. Air compressors and sources of power.
9. Requirements of a pressure cabin experimental aeroplane.

In the final conclusions the authors state:—

"There is absolutely no doubt about the possibility of supercharging aeroplane cabins for the purpose of high altitude flying. There are, however, a great many problems to be overcome before the pressure cabin can be made practical. The entire project is one of making a great many devices operate satisfactorily all at the same time."

*The Torsional and Bending Deflection of Full-Scale Aluminium Alloy Propeller Blades Under Normal Operating Conditions.* (E. P. Hartman and D. Biermann, N.A.C.A. Report No. 644, 1938.) (65/28 U.S.A.)

The torsional deflection of the blades of three full-scale aluminium-alloy propellers operating under various loading conditions was measured by a light-beam method. Angular bending deflections were also obtained as an incidental part of the study.

The deflection measurements showed that the usual present-day type of propeller blades twisted but a negligible amount under ordinary flight conditions. A maximum deflection of about 1/10° was found at a $V/nD$ of 0.3 and a smaller deflection at higher values of $V/nD$ for the station at 0.70 radius. These deflections are much smaller than would be expected from earlier tests, but the light-beam method is considered to be much more accurate than the direct-reading transit method used in the previous tests.

*Recent Developments in Piston Ring Materials.* (B. A. Yates, J.S.A.E., Vol. 44, No. 2, February, 1939, pp. 49-58 (Transactions).) 65/29 U.S.A.)

The importance of the material of the piston ring has too long been relegated to the background as compared with such design factors as ring proportions, ring loadings, circularity, point pressure, and so on; therefore, this paper concentrates on the material factors—such as composition, structure, and surface finish—which should go into the modern piston ring. The causes of piston-ring wear are analysed and classified under three headings—abrasion, corrosion, and erosion.

Various types of coating materials, both metallic and non-metallic, employed to reduce the severity of scuffing or scoring, are considered. From test results it appears that superficial coatings reduce piston-ring wear from scuffing and erosion, and that a very thin coating of tin was more effective than other types of metallic and non-metallic coatings.

*Recent European Developments in High Speed Diesel Engines.* (P. M. Heldt, J.S.A.E., Vol. 44, No. 2, Feb., 1939, Transactions, pp. 77-84.) (65/30 U.S.A.)

The two-stroke cycle is in the ascendancy in European Diesel engine development, especially for aircraft, even though most of the European Diesels operating

to-day, with the exception of the Junkers, are of the four-stroke cycle type. The author explains that automotive-type Diesel engines are being used much more extensively in European countries than in the United States, principally because of the much greater difference between the cost of carburettor-engine fuels and Diesel fuels in Europe.

Of 176 European automotive Diesels for which specifications were published recently in Automotive Industries, Mr. Heldt points out that 55 have direct injection; 53 have precombustion chambers; 49 have turbulence chambers; and 19 are the air-chamber type.

*Co-ordinating Aircraft Engine Design and Production.* (A. H. Leak, J.S.A.E., Vol. 44, No. 2, Feb., 1939, Transactions, pp. 85-92.) (65/31 U.S.A.)

Close attention to the following items is necessary to produce and maintain satisfactory production designs:—

1. Carefully developed design and test programs are essential to develop advanced engines and details by orderly and logical processes.
2. Standardised engineering and drafting practices are a necessary part of any engineering organisation to maintain drawing consistency.
3. Close co-operation between production and engineering departments, starting with the original design and manufacture of experimental parts, is particularly important.
4. The utilisation of developed units and parts on new models when practicable. The desirability of reducing the total quantity of different parts made is evident to facilitate manufacture and servicing.
5. Consideration of suggested changes from all sources to simplify production and reduce costs.
6. Adequate quality and finish control. Finishes usually are controlled by samples, but the development of instruments to measure finish accuracy will assist materially in establishing a more precise control.

*Correction of Temperatures of Air-Cooled Engine Cylinders for Variation in Engine and Cooling Conditions.* (O. W. Schey, B. Pinkel and H. H. Ellerbrock, Jr., N.A.C.A. Report No. 645, 1938.) (65/32 U.S.A.)

Seven conventional air-cooled engine cylinders enclosed in jackets and cooled by a blower were tested to determine the effect of cooling-air temperature and carburettor-air temperature on cylinder temperatures. The cooling-air temperature was varied from approximately 80°F. to 230°F. and the carburettor-air temperature from approximately 40°F. to 160°F. Tests were made over a large range of engine speeds brake mean effective pressures, and pressure drops across the cylinder.

CONCLUSIONS.

1. The values of the cylinder-temperature correction factors for cooling-air temperature for constant engine conditions and constant mass flow calculated from semi-empirical equations agree reasonably well with the experimental values.

2. The cylinder-temperature correction factors are lowest for the constant-mass-flow condition and highest for the constant-velocity condition.

3. The cylinder-temperature correction factors for a fast climb are slightly higher than those for a slow climb when the cylinder temperatures do not attain equilibrium in the fast climb.

4. A change in carburettor-air temperature affects the cylinder-temperature correction factors by changing the effective gas temperature, but the effect is small.

5. It is recommended that the average of a number of thermocouples on the cylinder head and barrel be used as a measure of the head and barrel temperatures. A single thermocouple, especially one located on the rear spark-plug gasket, may give misleading results.

*The Combustion Gas Turbine.* (A. Meyer, The Engineer, Vol. 167, No. 4338, 3/3/39, pp. 291-294.) (65/33 Switzerland.)

The brake thermal efficiency of any heat engine depends on:—

(1) The thermal efficiency of the heat cycle adopted.
(2) The efficiency of compression.
(3) The efficiency of expansion.
(4) The ratio of negative to positive work.

In the case of the gas turbine working on the constant pressure cycle, the compression pressure is usually of the order of 20-30lb. per sq. in. This necessarily means that the thermal efficiency of the cycle is small. The heat addition is limited by the fact that the blade temperature in continuous operation must not exceed 550°C. The ratio of negative to positive work is thus large and the brake thermal efficiency depends almost entirely on the efficiency with which the compression and expansion can be carried out. Under these conditions it is easily shown that the combination of turbine and compressor can only do useful work if the turbine efficiency amounts to 78 per cent. and that of the compressor to 68 per cent. It is only recently that such efficiencies have become possible and although axial blowers are now available with compression efficiencies as high as 85 per cent. and turbine efficiencies of the order of 90 per cent. appear possible, the overall efficiency of the turbine is not likely to rise above 20 per cent. unless the limiting blade temperature can be raised. In certain fields of application, however, such an efficiency is sufficient and several plants are now running both in America and on the continent.

*Power Loss Accompanying Detonation.* (N. McCoull, J.S.A.E., Vol. 44, No. 2, Feb., 1939, pp. 34-5.) (65/34 U.S.A.)

In tests on a single-cylinder CFR engine, as the compression was raised above the critical compression ratio, the author found that:—

1. Power output increased steadily with compression ratio if the spark advance was adjusted for maximum power at each ratio. The limit apparently was set by pre-ignition.
2. If the spark was retarded to the threshold of knock at each compression ratio, the power increased and then dropped off rapidly at higher compressions.
3. Temperatures of spark plug, piston, and intake valve, rose with compression ratio even when free from detonation, but compression ratios above the critical did not cause excessive temperatures.
4. Temperatures of exhaust gas and exhaust valve, as well as heat losses to jacket, were lowered with increased compression ratio, even during detonation, when the spark was set for maximum power.

As a result the author concludes that the octane requirements may be appreciably lowered by retarding the spark at the cost of a trivial power loss.

*Fabric Fuel Tanks (Mareng Fuel Cell).* (Sci. Am., Vol. 160, No. 3, March, 1939, p. 162.) (65/35 U.S.A.)

Bags of treated fabric are designed to the shape of the interior compartment of wings, fuselage, or floats and are inserted in place somewhat as inner tubes are installed in tyre casings. The bag is oversize in the sense that it rests against the surrounding walls of the structure and is not subjected to stretching or twisting.

A great advantage of this type of fuel container is its relative immunity to bullets, since the resulting slit has a tendency to close. A tank of this type was pierced by enemy bullets on a foreign war front (Spain?), but the leakage was so small that the aircraft could return to its base more than 100 miles away.

It is stated that the fabric tank has successfully withstood stringent official vibration tests.

*Secondary Reference Fuels for Use in the Determination of Octane Numbers.* (Report by the Knock-Rating Aviation Fuels Panel, Inst. of Petroleum, J. Inst. Petrol, Vol. 25, No. 134, Feb., 1939, pp. 106-108.) (65/36 Great Britain.)

The Standard Oil Company of New Jersey have manufactured three secondary reference fuels known respectively as A, C and F.

The range 79-93 octane number is best covered by reference fuel C plus tetraethyl lead up to 4 mls. per imperial gallon.

The range 93-100 (102 with extrapolation) is covered by blends of C and F fuels, each containing 4 cc. of tetraethyl lead per imperial gallon.

The calibration curve by the C.F.R. motor method is of the following form :—

| Octane No. | Per cent. Volume of $F_1$ in $F_1/C_{10}$ Blend. |
|---|---|
| 93 | 0 |
| 96 | 20 |
| 98 | 30 |
| 100 | 38 |
| 102 | 45 |

*Some Recent Work on the Problem of Automatic Control.* (R. Wilde, Collected Papers of the Lilienthal Society, 1938, pp. 243-247. In course of translation.) (65/37 Germany.)

The increased speed range and reduced aerodynamic damping of modern aircraft makes automatic control more difficult. At the same time the need for such control gear is becoming increasingly urgent for reducing the strain on the pilot and rendering blind starting and landing possible.

The author deals in detail with the latest Askania instruments for automatic control (course setting gyro, pre-corrector gyro responding to angular acceleration, electro-hydraulic servo motor, artificial horizon, etc.).

In the complete (three component installation) all the gyroscopes are placed in a separate control box which is housed in a suitable position on the aircraft. This is important since most modern high speed aircraft are subject to fuselage vibration which might induce a dangerous gyro precession. The precorrector gyro utilises an ingenious air jet control for transmitting the necessary steering impulse. (When measuring acceleration the deflection of the vertical gyro frame must be kept very small.)

The weights of the Askania instruments are very low. A complete servo motor (oil pump with electric motor and relay) weighs 6.5 kg. and will transmit a power of 5 kg. m./sec.

A course setting installation (gyro course setter, precorrector and servo motor) weighs 11 kg., whilst the full automatic control about three axes weighs 45 kg. completely installed.

*The Principle and Constituent Elements of Automatic Steering Apparatus for Aircraft.* (E. Fischel, Collected Papers of the Lilienthal Society, 1938, pp. 231-236. In course of translation.) (65/38 Germany.)

The general law of control which must be satisfied by any steering gear is of the form

$$\beta = a\phi + bd\phi/dt + c\int \phi dt$$

$\beta$ = deflection of rudder.

$\phi$ = deviation of aircraft from set course.

$a$, $b$, $c$ = design constants.

$bd\phi/dt$ controls the damping and $c\int \phi dt$ deals with permanent disturbances.

The steering gear may satisfy the above law directly, by co-ordinating the rudder position with the control impulse or the more indirect method of co-ordinating impulse and speed of rudder operation may be adopted. In the case of " direct position control," the control units respond to the course angle, angular velocity and time integral of course. For " rudder movement control," we require angular velocity, angular acceleration and course angle, *i.e.*, the time derivatives of the first set of factors. The author discusses the relative advantages of these two methods and then describes in greater detail constituent elements such as course setting gyro with magnetic control (type Siemens), artificial horizon, damping gyroscopes and servo motors. Complete steering installations with three axes control are next discussed, including the possibility of automatic curvilinear flight.

Application to bombing and automatic landings are briefly touched upon.

*The Importance of Automatic Steering in Aircraft Design.* (G. Klein, Collected Papers, Lilienthal Society, 1938, pp. 237-272. In course of translation.) (65/39 Germany.)

Automatic control gears must not only satisfy the general flight conditions as regards design and installation, but must also take into account the aerodynamic characteristic of the aircraft. The best results can only be obtained if there exists complete co-operation between the aircraft and instrument designer. If the aircraft possesses suitable characteristics, automatic rudder control alone (automatic course setting) will also very materially affect the motion above the other two axes, and may thus be well worth while adopting on its own merits, at any rate on smaller sized aircraft. For the heavier machines, automatic three-component control is however generally fitted. The weight of such a gear depends primarily on the magnitude of the control force required and here again the aircraft designer can help. The author gives flight records showing the relative accuracy of manual and automatic flight control, showing the great superiority of the latter. The course setting gyro will keep course to 0.6° in gusty air. Under favourable circumstances, similar accuracy is obtainable for roll and pitch. Long distance record flights have demonstrated reliability under working conditions. Certain pilots appear to resent the installation of automatic gears as a reflection on their piloting capacity. Once, however, the accuracy of automatic control is more fully realised, such prejudice will rapidly disappear.

*Magnaflux—What Does it Show?* (J. B. Johnson, J.S.A.E., Vol. 44, No. 2, February, 1939, Transactions, pp. 56-67.) (65/40 U.S.A.)

Magnaflux testing means the detection of defects in magnetised metal with para-magnetic powder.

Magnaflux testing has become an important adjunct in connection with the inspection of aircraft parts fabricated from magnetic materials. The method is very sensitive and may indicate not only defects which seriously weaken the part, but also non-injurious imperfections. The author has classified the several defects indicated by magnaflux which have been found in the routine inspection and examination of a large number of parts which have been in service in engines, aeroplanes, and accessories operated by the U.S. Army Air Corps.

*The Stability of a Cylindrical Shell by the Method of Integral Equations.* (N. Swolinsky, C.A.H.I., Report No. 320.) (65/41 U.S.S.R.)

The author considers the case of a freely supported cylindrical plate of rectangular plan subjected to tangential forces at the circumference.

The system of approximate differential equations (originally due to Donnell) has already been discussed by the author in a previous report (C.A.H.I. No. 246). the solution leads to the Fredholm type of integral equation possessing an unsymmetrical core.

The results are finally compared with those given by the Ritz method.

*The Equilibrium and Oscillation of Rods Under Torsion.* (S. Tumerkin, C.A.H.I. Report No. 341.) (65/42 U.S.S.R.)

The author shows that the methods of Gallerkin and Ralley-Ritz when applied to problems of torsion suffer from certain defects. As a result of these investigations, a modification of the Ralley-Ritz method is proposed which is sufficiently accurate even in complicated cases.

The effect of centrifugal force on the vibration frequency is also considered and a number of examples are worked out numerically.

*Impact Bending Force Produced by Distributed Load.* (K. Leiteisen, C.A.H.I., Report No. 351.) (65/43 U.S.S.R.)

After discussing the theory of Saint Venant on the impact forces due to a concentrated load, various cases of distributed load are considered.

The initial conditions for concentrated and distributed load are compared and a certain number of experiments are discussed.

*Welding Coated Steel.* (W. Spraragen and G. E. Claussen, Welding Journal, February, 1939, pp. 33-43. Metropolitan Vickers Technical News Bulletin, No. 650, 3/3/39, p. 4.) (65/44 Great Britain.)

This report consists of a review of the literature to July 1st, 1937, and discusses spot welding, fusion welding and bronze welding of galvanised iron; fusion and spot welding, iron pick-up, mechanical properties, and flame cutting of nickel clad steel, and welding problems relating to Monel-clad steel, Inconel-clad steel, stainless-clad steel, tin plate, Terne plate, chromium plated steel, cadmium plated steel, aluminium and copper-clad steels and oxide coated steel. The report closes with some suggested research problems. Illustrated with six tables and three diagrams.

*Heterostatic Loading and Critical Astatic Loads.* (L. B. Tuckerman, Bur. Stan. J. Res., Vol. 22, No. 1, January, 1939, pp. 1-18.) (65/45 U.S.A.)

Southwell has shown how, in some cases, it is possible to compute the critical astatic load, that is, the elastic buckling load, of a structure from measurements of its heterostatic deflections at lower loads. The history of the theory of heterostatic loading and Southwell's method is briefly reviewed. Westergaard's general theory is then applied to the problem. It is shown that Southwell's method and Lundquist's modification of it are theoretically accurate for results of measurements which are proportional to the value of any one astatic parameter. These measurements need not be deflection measurements, but may be strain measurements or, theoretically, measurements of any effect linearly dependent upon the deformation. Further, the parameter need not be the parameter corresponding to the lowest critical load but, theoretically, may correspond to any higher critical load.

Southwell's method is thus useful in cases where measurements within the elastic range can be made to depend primarily upon the change of a single astatic parameter. The theory is valid only for cases in which the buckling loads are lower than the load at which appreciable plastic deformation of the material or appreciable deviation from Hooke's law would occur. If, even within the elastic range, the measurements are affected appreciably by changes in other parameters, the critical elastic load computed by Southwell's method or Lundquist's modification may still be considerably in error. A combined numerical and graphical method of computation is outlined which by successive approximations, gives more accurate results in such cases. Finally, experimental results are given in which the second and third critical loads of a " round-end " Euler column are computed from strain-gauge measurements taken at loads below the first critical load.

*Alloy Steel Containing Lead.* (G. Ledlov, Mechanical World and Engineering Record, 3/3/39, pp. 222-3. Metropolitan Vickers Tech. News Bulletin, No. 051, 10/3/39, p. 3.) (05/46 Great Britain.)

The introduction of lead into steel to form a homogeneous structure is complicated by its insolubility in solid steel, and low miscibility in the liquid state. Satisfactory production methods have now been developed, and machining and working tests taken. It is claimed that the new alloy improves machinability, allows higher cutting speeds with smaller tool wear, permits normal case-hardening, and possesses similar properties to non-lead bearing steel with regard to quenching, tempering, and fatigue.

Illustrated with five photographs and four diagrams.

*Boiling Film Heat Transfer Coefficients in a Long Tube Vertical Evaporator.* (G. W. Stroebe, E. M. Baker and W. L. Badger, Ind. and Eng. Chem. (Industrial Edition), Vol. 31, No. 2, February, 1939, pp. 200-6.) (65/47 U.S.A.)

Film coefficients are given for water, sugar, and " Duponol " solutions, boiling in a long tube vertical evaporator, equipped with a single 20-foot tube, under a wide range of conditions. From the data obtained, an empirical correlation of the coefficients is derived, expressing the coefficients in terms of the Prandtl number, surface tension of the liquid, specific volume of the vapour, and average temperature drop across the liquid film; all of these are based on the average temperature of the boiling liquid.

A relation between the average liquid temperature and the vapour temperature is derived, from which the average liquid temperature can be predicted from variables usually known to the commercial designer.

An explanation for the effect of the several variables is given in the light of this and previous investigations, and of certain known factors affecting the mechanism of boiling in the tube.

*Steam Film Heat Transfer Coefficients for Vertical Tubes.* (E. M. Baker, E. W. Kazmark and G. W. Stroebe, Ind. and Eng. Chem. (Industrial Edition), Vol. 31, No. 2, February, 1939, pp. 214-8.) (65/48 U.S.A.)

Steam film coefficients for a two-inch o.d., 20-foot long vertical tube are correlated by means of the usual non-dimensional co-ordinates. Other data for tubes 8 feet and 12 feet long are also correlated on the same basis and found to deviate from those for the 20-foot tube by a factor of $L^{\frac{1}{4}}$. No apparent break in the curve, indicating viscous and turbulent flow, could be observed, though it is believed that turbulence must occur over at least part of the tube, It appears, therefore, that turbulence in the steam condensate film does not control the rate of heat transfer, within the range of these experiments.

*Invisible Glass.* (K. B. Blodgett, Sci. Am., Vol. 160, No. 3, March, 1939, p. 160.) (65/49 U.S.A.)

A new process for suppressing glare due to reflection from glass surfaces has been developed by K. B. Blodgett, of the Research Laboratory of the G.E.C.

The glass is treated by dipping it into a tank of liquid on the surface of which is a film of insoluble soap only one molecule thick. Repeated immersion and withdrawal gradually builds up a layer on the glass equal in thickness to one quarter wave length of light. This layer is transparent and the resultant interference between the light reflected from the top and bottom surface causes all trace of reflection to disappear. Objects viewed through the glass therefore appear as if the glass were absent.

The process is still in the experimental stage, but hope is expressed that this non-glare treatment may have ultimately a wide application.

*The Sectoral Electro-magnetic Horn.* (W. L. Barrow and F. D. Lewis, Proc. Inst. Rad. Eng., Vol. 27, No. 1, Jan., 1939, pp. 41-50.) (65/50 U.S.A.)

An electro-magnetic horn radiator, two of whose opposite sides are flared, the other two being parallel, was studied experimentally at wave lengths between 40 and 100 centimetres. For comparison, measurements on parabolic reflectors and broadside arrays were also made. By virtue of its unusual freedom from secondary lobes and stray radiation, its ability to operate well over a broad band width, its simple construction, and its ease and stability of operation, the electro-magnetic horn offers unique possibilities as a directive radiating system for micro-wave applications. These results and the application to a straight-line blind-landing system for aeroplanes are discussed.

*Theory of the Electro-magnetic Horn.* (W. L. Barrow and L. J. Chu, Proc. Inst. Rad. Eng., Vol. 27, No. 1, Jan., 1939, pp. 51-64.) (65/51 U.S.A.)

A theoretical analysis of the operation of the electro-magnetic horn " antenna " is derived from Maxwell's equations. The details apply to a horn of sectoral shape. The analysis also applies to a tapered hollow pipe transmission line. Certain transmission quantities, like the phase constant, attenuation constant, velocity of propagation, etc., are calculated for horns of any angle of flare and the field configuration within the horn is plotted. One result is a clear understanding of the propagation of waves within the horn. Another result is that design specifications for horns may be established. Calculations of radiation patterns made by this analysis agree satisfactorily with experiments.

*L.M.T. Blind Landing Systems.* (Inter. Avia., No. 621, 24/2/39, pp. 6-7.) (65/52 France.)

In the system developed by Le Materiel Telephonique (L.M.T.), vertical navigation is carried out by means of an independent transmitter employing a special antenna composed of four elements. The waves are polarised horizontally and the following advantages are derived:—

(1) Flat glide path.

(2) Humidity of ground has no effect.

(3) Absence of interference between vertical and directional navigation, since the latter employs vertically polarised waves.

The starting point of the glide is 4.5 km. from the landing field and the average slope of the glide path curve is 6.6 per cent. Out of twenty-two different approaches carried out under blind conditions, on different days only one showed a variation of more than 12 m. from the standard altitude of 66 m. at a distance of 1,000 m. from the glide path transmitter. Twenty of the landings had the correct altitude within 10 m.

No difference in the vertical localisation could be detected for lateral deviation of $\pm 10°$ from the centre line of approach.

*Electrical Equipment of the Airship " LZ 130."* (E. Hilligardt, E.T.Z., 16/2/39, pp. 185-9. Metropolitan Vickers Tech. News Bulletin, No. 649, 24/2/39, p. 6.) (65/53 Germany.)

The electrical equipment of the airship " LZ 130 " is described in so far as it differs from that of the " LZ 129," of which details were given in E.T.Z. 57 (1936), page 354. The use of three-phase current in place of D.C. has led to a saving of 18 per cent. in weight. The utilisation of the exhaust and cooling water heat of the 40 h.p. Diesel engines for cooking and water heating made possible a reduction of 7.2 kw. in installed capacity and resulted in a saving in weight of 300 kgs. Illustrated with five diagrams and three photographs.

*Model Experiments on the Radiation Characteristics of Fixed Short Wave Aircraft Antennæ.* (E. Harmening and W. Pfister, H.F. Technik., Vol. 53, No. 2, February, 1939, pp. 41-45.) (65/54 Germany.)

The model aircraft represented Ju 52 to 1/18 scale and was fitted with a small transmitter emitting on 5 m. This corresponds to a 90 m. wave length on the full-scale aircraft.

The radiation characteristics were obtained along the three principal axes of the model, the latter being mounted on a wooden tower 50 m. high. The receiver was placed on a similar tower at a distance of 50 m.

It appears that the horizontal characteristic (diagram about the vertical model axis) is almost circular for the usual arrangements of the aircraft antenna.

A rod antenna has a pronounced directional effect depending on the locality of fixing.

*Metal Horns as Directive Receivers for Ultra-Short Waves.* (G. C. Southworth and A. P. King, Proc. Inst. Rad. Eng., Vol. 27, No. 2, February, 1939, pp. 95-102.) (65/55 U.S.A.)

The following paper describes some experiments made to determine the directive properties of metal pipes and horns when used as receivers of electro-magnetic waves. The experiments were of two kinds. One consisted of measurements of received power, with and without the horn in place, and the other of the determination of the directional patterns of the horns in two perpendicular planes. The results indicate that electro-magnetic horns of this kind provide a simple and convenient way of obtaining power ratios of a hundred or more (20 decibels). The effect of varying the several horn parameters are investigated. It is shown that there is an optimum angle of flare. The possibility of forming arrays of pipes or horns is mentioned.

*Marconi Ultra-Short Wave Aerodrome Approach Beacon Equipment.* (Inter. Avia., No. 623, 3/3/39, pp. 1-2.) (65/56 Great Britain.)

This equipment, known as A.D. 66, does not provide vertical guidance. It is thus not " 100 per cent. blind," but intended to assist aircraft in approaching aerodromes during conditions of poor visibility.

The most important difference between the A.D. 66 and other well known track systems is in the arrangement of the aerials, two parallel-series phase aerials with numerous vertical sections and a similar reflector system being employed instead of single dipoles. It is claimed that this arrangement increases the radiation along the main course (*i.e.*, reduces power output required) and reduces the interference with other short wave sets working in the neighbourhood to a marked extent. The installation works on the well known method of two equi-signal zones keyed E and T, the interlocking portions of which form the approach beam characterised by a continuous dash.

*An Improved Radio Meteorograph on the Olland Principle.* (L. F. Curtiss, A. V. Astin, L. L. Stockmann, and B. W. Brown, Bur. Stan. J. Res., Vol. 22, No. 1, January, 1939, pp. 97-103.) (65/57 U.S.A.)

A description is given of the construction and tests of a radio telemeter of high precision built according to the Olland principle, in which all indicating arms rotate on a common axis. Combined with a 5 meter radio transmitter of push-pull type, this telemeter provides a radio meteorograph which has been tested under actual working conditions and found to be reliable and accurate in its indications. Since it gives relatively strong signals with a good stability in frequency, it is easy to operate and very little retuning during an observation is required. Special attention has been given to the thermal insulation of the compartment containing batteries and transmitter so that no failures due to drop in

battery temperature have been observed even at altitudes above 60,000 feet. The cost of manufacture compares very favourably with that of other models recently developed in the U.S.A.

*Future Development of the N.A.C.A.* (Inter. Avia., No. 621, 24/2/39, pp. 5-6.) (65/58 U.S.A.)

In addition to the normal budget for 2.18 million dollars, a supplementary appropriation of 6.72 million dollars has been submitted. Of this extra sum, 4 million dollars are to be spent on a modern research station at Sunny Vale, California.

During 1938, the following research equipment was completed at Langley Field :—

(*a*) 19-foot pressure wind tunnel (3 atmospheres, 200 m.p.h.).
(*b*) 7½ by 3-foot refrigerated wind tunnel (ice formation).
(*c*) 12-foot freeflight wind tunnel.

A two-dimensional flow wind tunnel for work at very high Reynolds numbers is under construction.

The creation of a special laboratory for structural investigation on aircraft is stated to be very urgent.

In future a much closer liaison will exist between the Research Institute and the Civil Aviation Authority.

*Boots' Self-Locking Aircraft Nut.* (Inter. Avia., No. 621, 24/2/39, p. 6.) (65/59 U.S.A.)

The one-piece nut carries two threads, the smaller thread is slightly displaced against the bigger load carrying section, the two sections being connected by means of a tubular spring member. Upon inserting the bolt, the spring member extends till both thread systems engage and the resultant spring force prevents the nut from unscrewing.

It is stated that the device has been approved by the Civil Aviation Authority (U.S.A.).

*Numerical Computation and Application of Certain Function Related to Bessel Functions.* (R. Muller, Z.A.M.M., Vol. 19, No. 1, Feb., 1939, pp. 36/54.) (65/60 Germany.)

The author gives numerical tables for Bessel and Hankel functions of the first kind, zero order for purely imaginary arguments as well as for the function

$$\phi(x) = \int_0^{\frac{\pi}{2}} e^{-x \sin t} dt$$

and its derivative $d\phi/dx$.

These letter functions are of importance in the theory of wing vibration.

The author shows how by means of the tables provided the solution of the non-homogeneous Bessel differential equations associated with the forced vibration of elastic cylindrical bodies can be carried out, the disturbance function being expressed in the form of a power series with whole positive and negative exponents.

## LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the supply of copies of translations mentioned below should be addressed to the Under-Secretary of State (R.T.P.), Berkeley Square House, W.1, and will be supplied, free of charge, as far as availability of stocks permit. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

### AERODYNAMICS AND HYDRODYNAMICS.

| TRANSLATION NUMBER AND AUTHOR. | TITLE AND JOURNAL. |
|---|---|
| X96 Lennertz, J. ... ... | *Contribution to the Theoretical Treatment of the Mutual Interference of Wings and Fuselage.* (Zeitschrift fur Flugtechnik und Motorluftschiffahrt, No. 1, 14/1/27.) |
| 477 Gutin, L. J. ... ... | *The Sound Distribution Around a Rotating Airscrew.* (J. Applied Physics, Leningrad, Vol. 6, No. 5, 1936, pp. 899-909.) |
| 834 Cicala, P. ... ... | *On the Non-Steady Motion of a Wing of Finite Aspect Ratio.* (Atti della Reale Accademia Nazionale del Lincei, Vol. 26, No. 3-4, 1937, pp. 97-102.) |
| 835 Cicala, P. ... ... | *On the Problem of Wing Vibration (Theory and Experiment).* (L'Aerotecnica, Vol. 18, No. 4, April, 1938, pp. 412-33.) |
| 837 Malavard, L. ... | *The Application of Electrical Analogies to Some Aerodynamic Problems.* (E.N.S.A., No. 1, Jan.-Feb., 1937, pp. 62-73; No. 2, March-April, 1937, pp. 5-12; and No. 7, Jan.-Feb., 1938, pp. 39-50.) |
| 847 Doeppe, P. von ... | *Unexplained Problems of Static Longitudinal Stability.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 226-8.) |

### AIRCRAFT.

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| 792 —— ... ... ... | *Swedish Airworthiness Requirements.* (Circular issued by the Swedish Civil Aviation Authorities, No. 2, 1938.) |
| 804 Sitin, V. A. ... ... | *The Wind Factor.* (Civil Aviation, U.S.S.R., Vol. 8, No. 6, June, 1938, pp. 8-11.) |
| 807 —— ... ... ... | *Combat Planes Blohm and Voss, Ha 137B.* (Rev. de l'Arm. de l'Air, No. 109, Aug., 1938, pp. 938-42.) |
| 820 —— ... ... ... | *Fighting Aircraft of the Japanese Air Force.* (Air Fleet News, U.S.S.R., Vol. 21, No. 7, July, 1938, pp. 93-101.) |

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| 832 Immler, W. ... ... | *Position Finding by Wireless.* (L.F.F., Vol. 15, No. 8, 20/8/38, pp. 409-25.) |

| TRANSLATION NUMBER AND AUTHOR. | TITLE AND JOURNAL. |
|---|---|
| 833 Bruger, H. ... ... | *Survey of Experience Gained with the Short Wave Service in the Deutsche Lufthansa A.G.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. III, 1937, pp. 67-8.) |
| 841 Brunswig, H. ... | *Investigations on Taking Bearings with Simple Frame Aerials.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. 3, 1937, pp. 81-3.) |
| | ARMAMENTS. |
| 719 Glazov ... ... | *Simplified Calculation of the Angular Correction for the Speed of a Target and the Firing Range.* (Air Fleet News, U.S.S.R., Vol. 20, No. 1, January, 1938, pp. 38-40.) |
| 777 Nikitin, A. ... ... | *Aerial Firing—The Chief Method of Defending Bombing Aircraft.* (Air Fleet News, U.S.S.R., Vol. 20, No. 6, June, 1938, pp. 39-41.) |
| 803 Kourensky, M. M. ... | *Note on External Ballistics (Fundamental Ballistic Problem).* (Memorial de l'Artillerie Francaise, Vol. 16, No. 3, 1937, No. 63, pp. 767-784.) |
| 842 Langweiler, H. ... | *Development and Experimental Testing of Self-Contained Mathematical Expressions for Quantities in Internal Ballistics, Especially Those for Maximum Gas Pressure and Muzzle Velocity.* (Z.G.S.S., Vol. 33, Nos. 10, 11 and 12, 1938, pp. 273-6, 305-9, and 338-42.) |
| | PHOTOGRAPHY. |
| 798 Schmieschek, U. ... | *Increasing the Sensitivity of Commercial Ortho-chromatic, Pan-chromatic, and Infra-Red Sensitive Emulsions by Means of Alkaline Solution of Gold Salts, as well as by Other Hypersensitising Baths.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. 3, 1937, pp. 99-103.) |
| 839 Schmieschek, U. ... | *The Application of Infra-Red Rays in Photography.* (Jahrbuch der Deutschen Luftfahrtforschung, 1937, Vol. 3, pp. 93-8.) |
| 840 Schmieschek, U. ... | *Systematic Investigations on the Different Suitabilities of the Ortho-chromatic, Pan-chromatic and Infra-Red Sensitive Emulsions for Aerial Photography.* (Jahrbuch der Deutschen Luftfahrtforschung, 1937, Vol. 3, pp. 84-92.) |

## REVIEWS.

DIPL.-ING. B. KLINKER: ELEKTRISCHE FLUGZEUGAUSRUESTUNG (Electrical Equipment for Aeroplanes). Vol. 5 of "Luftfahrt-Lehrbuecherei." Berlin, 1938. Publ. by Dr. M. Matthieser and Co., 147 pp., 150 figs., 4 tabl. Price RM. 3.80.

The electrical equipment on board modern aeroplanes has gradually become so extensive that there is need for treatises dealing with this side of aeronautical construction. The least which can be said of this book is that it is clearly and instructively written, that it is by no means a mere copy of firm catalogues, and that it seems to cover the whole field.

The author treats, at first, the general conditions under which electrical accessories have to work in aircraft and discusses the constructional requirements. Electrical wiring diagrams for aeroplane installations are explained. A subsequent chapter deals with methods for the generation of current on board. A voltage of 24 V. D.C. appears to have become standard, against formerly 12 V., and it is stated that a higher voltage does not seem to be of any advantage, especially with regard to batteries. The windmill drive for generators is considered obsolete, while the aero-engine driven generator has become general, except for big seaplanes in which an auxiliary engine is provided. The design of modern generators provides for a maximum driving speed of 20 per cent. over the diving r.p.m., for a short period. Compared with normal (car) generators, the output of special aircraft generators averages four times as much, due to a 50 per cent. increase in speed and to the cooling of collectors and brushes by a cooling air duct. Batteries have been improved as well. Their life is assumed to be about two years, with proper and regular maintenance. With regard to fuses, the "lazy" type is preferred in order to permit overloading for a short time. Automatic switches are superseding the normal cut-out fuses. They are also provided with a delayed action.

The book gives a number of practical examples of modern wirings and installations, including the electrical ignition systems of engines, lighting, searchlights, electric motors for retractable undercarriages, v.p. airscrews, various instruments with electrical transmission, etc. The signs and symbols standardised for aeronautical installation purposes are also given.

The book is up-to-date and will be of interest to all concerned with electrical installation problems.

EXAMPLES AND CHARTS FOR AIRCRAFT DRAUGHTSMEN.

By H. Parkinson, A.M.I.Ae.E. Published by Sir Isaac Pitman and Sons, Ltd. Price 6/-.

This book is intended to assist the draughtsman to solve the angular problems which occur so often in the design of aircraft, such as the precise angle of a lug, when an angle occurs in two views. It has the advantage of a larger layout than most books of its class, which helps considerably in improving the size of the numerous diagrams, which are consequently much easier to read.

The various examples discussed are fairly representative of the class of problem which is often met with in detail design, but there is a certain tendency to complicated explanations which is undesirable in a work of this type. Take, for instance, example 15. This is the case of a lug attached at one end of a pin-jointed tube. A tensional load is applied to the lug so that the line of action of this load passes through the centre of one of the pin joints of the tube. The author states wrongly in his first paragraph on this example that the tube is subjected to bending. Actually there are two equal and opposite bending

moments on the tube which cancel out. There is, of course, a small bending moment on the fitting. Had this fact been pointed out at the commencement much of the work could have been saved. It is obvious from the conditions of the case that there can be no bending moment on the tube.

The last chapter contains a useful collection of charts and general data which should save a considerable amount of computing, and there is a useful chapter on the calculations necessary in the design of seaplane floats.

PRACTICAL AIRCRAFT STRESS ANALYSIS.

By D. R. Adams, A.F.R.Ae.S. Published by Sir Isaac Pitman and Sons, Ltd. Price 8s. 6d.

This is the second edition of this work. It contains the same matter as the previous edition, but opportunity has been taken to correct a few minor errors.

The author is the lecturer on Stress Analysis and Design at the De Havilland Aeronautical Technical School, and it is evident from the clearness of exposition that he has appreciated the difficulties of the student in grasping points previously unfamiliar.

The book should also be useful to the draughtsman who is desirous of improving his knowledge of aircraft stress matters, and it is hoped that many of those who read it will be encouraged to study more advanced textbooks. There are a number of tables of useful information and the diagrams given are clear and adequate in number.

SCIENCE FOR THE CITIZEN.

By Lancelot Hogben. Published by George Allen and Unwin, Ltd. Price 12s. 6d.

The importance of teaching the general public the main facts of scientific progress cannot be exaggerated. Unfortunately, there are several difficulties in the way, one of which is that many of the prospective pupils have the greatest objection to being taught anything, and may even consider the attempt to do so as an impertinence. Another difficulty is to find an author who really understands the subject he proposes to teach, in fact one who understands it so well that he can explain the outline of it to the intelligent uneducated, or even to those who are not particularly educated. To do this properly naturally requires a certain facility in English diction. A further difficulty, which is unsurmountable, occurs when the information to be imparted can only be given in terms of higher mathematics and therefore requires considerable mathematical knowledge to follow the argument, and to grasp the result. But it may be permissible to some of us to doubt whether certain of these latter cases represent real knowledge, or whether it merely happens that a particular mathematical process fits the observed facts. The formulæ dealing with the deflection of a soap film are similar to those which describe torque stress in shafts. and in the case of shafts of irregular section it may be useful to determine the shear stress by experiments with the soap film, but there is obviously no resemblance between these two phenomena, except that the mathematical expressions which describe them are similar.

It follows, therefore, that in writing such a book as this Professor Hogben faces a considerable difficulty. As far as my memory serves, most of his predecessors, such as Frank Buckland, Huxley, Ray Lankester, etc., confined themselves mostly to biological subjects, being biologists, and did not write about other branches of science. Professor Hogben, although a biologist, does not confine himself to this subject, but deals with many others which are far removed from biology. In this way he has set himself an even more formidable problem. On the other hand, he assumes that his readers will have an elementary knowledge of mathematics. This assumption simplifies his task, or perhaps more correctly, is the only one which makes it possible; but it does so at the cost of being unintelligible to many who would like to understand him.

It now remains to look at the way in which the work has been done, and there can be no doubt that it is a brilliant piece of writing by a man who has all the necessary qualifications for the task. In the case of such a book it is easy to be critical, it might be thought that less space might have been used in discussing some of the less important aspects of astronomy, that such a book might be expected to contain some of the modern knowledge on the subject of aerodynamics, and that one gets the idea occasionally that Professor Hogben is inclined sometimes to regard his political opinions as scientific truths. But matters such as these are of minor importance, and every reader might differ in regard to them.

There can be no question that scientific knowledge is increasing faster than the capacity of the world to learn to use it properly. It seems that the human race is rather like a child which has been provided with a number of toys, which, when used properly, are capable of giving infinite pleasure and satisfaction, but if they are used improperly may turn round and injure the owner. The cure for this is obviously instruction in the nature of the toys which would give the knowledge necessary to use them safely and with benefit to the owner. It is in this direction that Professor Hogben is doing a most valuable work, for it is only by diffusing such knowledge to the human race that they will learn to use this modern knowledge properly, and, in doing so, will increase the well being and happiness of mankind. But, in order to enable such knowledge to be diffused as widely as possible, it is to be hoped that arrangements can be made to publish the work in a form that can be more easily purchased, as it is certain that many who will wish to possess it, and who ought to be encouraged to do so, will find the present price a serious obstacle.

INTERNATIONAL INDEX TO AERONAUTICAL TECHNICAL REPORTS.

Prepared by the Society of British Aircraft Constructors, Ltd., London, and published for and on their behalf by Sir Isaac Pitman and Sons, Ltd., 1939. 5/-.

This is the seventh annual issue of these reports, which have now become of high standing importance among the increasing number of aeronautical reference books available. The index is specially prepared to provide a rapid reference to reports for the use of designing staffs, and in this connection it is one of the best reference books published.

There are 1,320 references to papers published in 90 British, American and foreign periodicals during the period covered by the index. Out of the 1,320 references no fewer than 750 (56.5 per cent.) are to papers and abstracts in one periodical alone, the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

The index is prepared specially by the industry for the industry for use of designing staffs. The fact that more than half its references are to the Journal of the Society out of 90 periodicals is a tribute to the value of the Journal, which is outstanding.

DR. PH. LOETZBEYER: "PHYSIKFIBEL FUER DIE FLAKARTILLERIE" (Elementary Instruction for A.A. Gunners). Berlin, 1938. Publ. by Dr. M. Matthiesen and Co. (before by Dr. Max Gehlen). 217 pp., 238 figs., and tables. Price R.M. 2.40.

This booklet is an abridged guide for the technical instruction of A.A. gunners, searchlight and sound locator personnel. It deals with the fundamentals of mechanics, dynamics, heat, acoustics, magnetism, electricity and optics, and treats the principles of sound locators, arc lamps, telephone, wireless, range finder, and periscope in a very short but clear manner. The finishing chapters form an introduction into aerodynamics, meteorology, and into the mechanics of flight. A number of useful conversation tables is included. The book is very well written and might be of assistance to instructional officers.

*The 644th Lecture read before the Royal Aeronautical Society since its foundation on January 12th, 1866.*

A. G. VON BAUMHAUER, *Fellow.*

The lecture and discussion printed in the following pages appear in distressing circumstances. A. G. von Baumhauer gave his lecture before the Society on Thursday, March 2nd, 1939. After the lecture he was entertained to a dinner given by the President and a few days later sailed for the United States of America. On March 18th Mr. Baumhauer was killed when the Boeing Stratoliner crashed near Alder, State of Washington, U.S.A.

Albert Gillis von Baumhauer was the Chief Engineer of the Netherlands Government Technical Air Staff. He was born in October, 1891, at Heerenveen, in Holland, and studied at the Technical High School at Delft. In 1916 he went to Zurich and afterwards had four years' experience in aircraft construction.

For some years he was concerned with investigations on models, and particularly a helicopter, in the Aeronautical Research Department at Amsterdam. He made a special study of wing flutter and the breaking away of air flow from wing surfaces and its influence on stability. In 1931 he took his A licence as an aeroplane pilot and his C licence as a glider pilot. He invented a number of aircraft instruments.

A. G. von Baumhauer was a member of the Committee of Airworthiness for Civil Aircraft. Besides being a brilliant engineer and research worker, he was outstanding as a linguist. All those who heard his lecture and reply in English will appreciate his extraordinary ability in this direction. A man of great charm, one who never made an enemy, his loss is not only a very severe one to world aviation, but one which will be long felt by a very wide circle of friends in many countries.

He joined the Society in April, 1924, as an Associate Fellow and was elected a Fellow of the Society in 1938.

## PROCEEDINGS.

A meeting of the Royal Aeronautical Society was held in the hall of the Institution of Mechanical Engineers, Storey's Gate, Westminster, London, S.W.1, on Thursday, March 2nd, 1939, when a paper on "Testing Stability and Control of Aeroplanes" was presented by A. G. von Baumhauer, Mech. Eng., F.R.Ae.S., of the Dutch Airworthiness Department.

Mr. A. H. R. FEDDEN (President of the Society) in the chair.

THE CHAIRMAN: In the first place, he extended to Mr. von Baumhauer a very hearty welcome, emphasising at the same time that he was a Fellow of the Society. Holland had long been famous for pioneer endeavour; they had become accustomed to connect that country with interesting aerodynamical developments, and in that respect they had never been disappointed. Mr. von Baumhauer was educated at Delft and afterwards at Zürich, and since then had had a wide experience of aerodynamics. For many years he had been engaged at the Amsterdam Aerodynamical Laboratory, and his work on flutter research was well known. He had also carried out a considerable amount of research on the helicopter. During the past few years he had been working in the Dutch Airworthiness Department, where he had been concerned with the very practical problems of design and testing. Thus, he had followed faithfully in the footsteps of many other Dutch pioneers, and was well qualified to deal with testing stability and control of aeroplanes.

Mr. VON BAUMHAUER, in presenting his paper, said that he felt greatly honoured, as a foreigner, in having been invited to present a paper to so famous a Society.

# TESTING STABILITY AND CONTROL OF AEROPLANES.

By A. G. VON BAUMHAUER, Mech. Eng., F.R.Ae.S.

The subject which I have to discuss to-day is one which can be treated from a standpoint of the scientist or from that of the practical engineer. I am going to try to discuss it from the latter point of view.

The testing of the behaviour of aeroplanes in flight, to which I want to draw attention, does not deal with research on stability and control, it only deals with checking the flying characteristics with regard to the requirements which should be fulfilled.

In the Dutch requirements for a certificate of airworthiness for civil aircraft there are several detail rules, which all tend to state that the aeroplane should be stable and well controllable within the whole region of flight, and for all conditions which may occur in normal and special use.

Before starting to discuss how the detail requirements have been defined, I want to make a few remarks on the sense of these requirements. In the first place on the requirements of stability.

## STABILITY.

Though I understand that several British aeronautical engineers do not appreciate this requirement, I want to emphasise its desirability.

In my opinion stability is a quality desirable for practically everything. If the equilibrium of any sort is not stable, we must expect undesirable happenings to come at an unexpected moment and in an uncomfortable way. This not only applies to aeroplanes, but also to the stability of a chair on which we sit, the economic position of a country or of world peace.

What we want for safety is that a state of equilibrium shall continue to exist if there is no disturbance and also that small disturbances shall only cause small effects. We want continuity, and a fair agreement or a simple relation between cause and effect.

I hope that you all will agree that the conception of stability is one of general value and in no way a special mathematical idea. The fact that the scientist or even a young student is able to express the desire for stability in mathematical language, does not prevent me from saying that stability is a quality with which the layman is familiar—and I may add—with which pilots should be familiar.

May I mention that I have got the impression that several designers here do not bother about stability, as they have been terrified by the elaborate amount of mathematical treatment bestowed on the problem of the stability of aeroplanes. If my impression is right, it is a pity that this work, to which so many splendid brains have given so much time and attention, should have achieved the contrary of what it aimed at. I think the fear of mathematical treatment has led several designers away from the standpoint of safety being incorporated in everybody's desire for stability.

Stability of an aeroplane means relief to the pilot from playing the rôle of a "stabiliser," thus allowing him to relax physically and to pay more attention to problems which cannot be solved by the aeroplane itself, such as questions of navigation. Our requirements do not prescribe the amount of stability which the aeroplane should possess—however, the stability has to be positive in the whole range of flying conditions. For blind flight a minimum amount is necessary for the prevention of overstraining the pilot. It is believed that the maximum is a question of comfort to the passengers, especially in bumpy weather.

CONTROLLABILITY.

The other point to which the requirements relate is controllability. There can be no doubt about the necessity of this quality.

I will not endeavour to discuss this problem which was so ably treated by Professor Hill at the meeting of this Society on the 1st of December, 1938. His subject, "The Flying Controls of the Aeroplane," was studied from the point of view of the pilot, especially with the object of giving him the easiest, most agreeable and most efficient controls. This may be the starting point for service machines. You will allow me, as a member of the Airworthiness Board of Civil Aircraft, to consider these problems in the first place from the point of view of safety. In civil aircraft, especially transport planes, we aim at having ease of control. That means little to control when cruising, and ease of handling when taking-off and landing.

In the second place we hope that aeroplanes will be such that errors of control will not have dangerous consequences.

This latter quality, also mentioned by Professor Hill, gives a margin of safety, a quality normally desired for structural strength.

The requirements for safe control may be described as follows:—The aeroplane should be such that it can be easily controlled under any condition. What is of utmost importance, the aeroplane should not—even under special conditions—have the tendency to escape from the pilot's control.

These principles, I believe, are so simple and so obvious, that everybody is willing to agree with their desirability.

We must admit, however, that a number of aeroplanes possess this bad tendency. Some of them are so common, *e.g.*, violent stalling, that many pilots believe that they are inherent to flying. The technical people should be aware of these awkward qualities and do their utmost to eliminate them. The requirements do not yet define the amount of controllability which aeroplanes should have.

Most requirements only deal with the stability and control *in flight*. They do not deal with control and stability during landing and take-off, perhaps because so very little is known of stability and control during these manœuvres, though they are of utmost importance for the safety of the flight.

Stability and control have nothing to do with the stability of vibrations of control surfaces, though these ill effects belong to the pathology of the aeroplane, the field of work which is dealt with in the testing of stability and control.

In several countries the requirements are rather vague, only going into detail for special points, *e.g.*, on longitudinal stability and stalling characteristics. In some rules the requirement is well defined, but the method of checking the quality is not described.

I will discuss more in detail the Dutch requirements and their methods of testing, as they are more familiar to me. In an appendix you will find the English translation of the "Test procedure," describing the methods and giving a list of questions, the answers to which may give information concerning how far and in what way the requirements are fulfilled.

TESTING.

In single-seaters the questions have to be answered by the pilot himself, who may be greatly assisted by using an "automatic observer." In most civil aeroplanes, especially transport machines, an observer can sit beside the pilot, so that readings of the instruments can be taken and direct contact with the pilot is maintained. The test observer has to know the programme, what to read, and be able to do so quickly. High technical training for this work is less necessary than ability to observe and freedom from air sickness. Some or a complete knowledge of piloting an aeroplane is useful.

In addition, I should like to make a remark on the responsibility for these tests.

The Civil Airworthiness Board in Holland now is of the opinion that the aircraft designer and constructor should be responsible for showing that the aeroplane not only fulfils the requirements with regard to structural strength, but also with regard to stability and control. In such a case the maker's report of the systematic flight tests plays the same rôle as the standard report on strength calculations.

We do not have " approved firms " yet, as you have got in England. Thus we check these reports, and in cases of doubt certain tests are repeated in the presence of an official. In this way the maker's test pilots are obliged to test the aeroplane systematically over the whole range of speeds and conditions, thus getting acquainted practically with all characteristics of the type of machine. The maker also learns in what respect the prototype does not comply with the requirements, and he has the opportunity to improve the machine before presenting it to the Airworthiness Board.

The questions take a form which we call Test Procedure, in which it is tried to be as exact and precise as possible in the questions dealing with stability and control, and to bring them on a more objective basis than is possible by only gathering the opinions of test pilots.

I do not deny that observations of highly experienced pilots are of great value. The fact that their opinions often differ widely is a warning not to base our judgment of an aeroplane only on these impressions.

It is necessary to try to interpret these subjective opinions in terms of more technical characteristics. In this respect I should like to mention the work of H. A. Soulé, who tried to correlate pilots' observations with results of measurements of the longitudinal stability of a number of aeroplanes.*

The requirements and the test procedure are far from being complete. It has been found necessary gradually to modify them, thus following the development of the aeroplane. It will be seen that only for some cases do we measure more or less directly the quantities on which stability depends. Some tests have been originally described in British reports, also in one report which deals with stability terms.

Though I will not describe the rather simple instruments which are used for the tests, I want to mention that most of the tests are based upon the accurate reading of the control positions. The absolute values are not important, but more the sense of the displacements when the speed or the attitude of the aeroplane is systematically altered.

In this way the control angle can easily be expressed as a fraction of the total control angle available. This not only applies to rudder angles, but also to elevator angles at or near the stall.

SUMMARY OF THE TESTS FOR CHECKING STABILITY AND CONTROL.

| | |
|---|---|
| 1. Static conditions: | Measurements: |
| *a*. Rectilinear symmetrical flight with fixed position of engine throttle with forward and rearward centre of gravity. | —elevator position for a series of speeds. |
| *b*. Rectilinear asymmetrical flight side slip for a few speeds. | —position of aileron and rudder for a series of banks. |
| *c*. Curvilinear flight for a few speeds. | —positions of controls for a series of banks. |
| *d*. (Semi-static) curvilinear flight for a few speeds, controls held fixed. (Does turn flatten or sharpen?) | —bank with time. |
| *e*. (Semi-static) symmetrical flight, control stick slowly pushed or pulled with given force, for a few speeds, from position of balance. | —change in control position, change in speed. |

* N.A.C.A., Report Nr. 578, 1936. Flight measurements of the dynamic longitudinal stability of several aeroplanes and a correlation of the measurements with pilot's observations of handling characteristics.

| | |
|---|---|
| 2. Quick control movement from and back to position of balance. | Measurements: |
| *a*. Rectilinear flight, elevator pushed or pulled, | —speed versus time. |
| *b*. Rectilinear flight, rudder kicked (R. and L.). | —bubble bank versus time. |
| 3. Going in and coming out of turn, a few values of bank. | |
| *a*. With all controls, | —time for figure 8, time for banking and for regaining level flight. |
| *b*. Only by rudder, | —time for banking and for regaining level flight. |
| *c*. Only by aileron. | |
| 4. Throttling or opening one or more engines. | |
| *a*. Symmetrical, | —pitching, control displacement, control force, what final speed with elevator free. |
| *b*. Asymmetrical, one or all engines on one side. | —yawing, rudder displacement, rudder force. |
| 5. Stalling. | |
| *a*. In rectilinear flight, rudder and aileron fixed, elevator gradually fully upward. | —speed at which longitudinal or lateral stability vanishes, aeroplane movements, effectiveness of controls. |
| *b*. In turns, | —idem. |
| *c*. If not unstable with elevator against rearward stop, | —what rudder and aileron movements allowable. |
| 6. Miscellaneous, swinging, oscillations, landing difficulties, etc. | —conditions. |
| Can the automatic pilot be over-controlled by hand. | |

With the object of limiting the number of tests, it is laid down in the test procedure that asymmetrical conditions need be tested only at two speeds—cruising speed and speed of best climb. For wings with high lift flaps a lower speed must also be chosen.

Modern aeroplanes are getting more and more complicated. The number of conditions under which aeroplanes have to fly increases rapidly. Consequently, several tests have to be repeated for these conditions, *e.g.*, with undercarriage up and down, wing flaps up and down.

Perhaps it will be found that automatically controlled blade angles of airscrews have an influence on the oscillations (dynamic stability).

## Methods of Testing and Some Results.

I will now discuss the different tests mentioned in the foregoing summary.

Point 1*a*, of course, is of special importance as this test deals with the statical longitudinal stability of the aeroplane.

In general it has been found that dynamical stability is present in the normal region of flight, if the statical stability is positive.

The longitudinally stable aeroplane, when being well controlled laterally, will neither get into a dive nor stall when the elevator is held fixed, or eventually when the elevator has been trimmed and the control is let free. With this quality the fore and aft safety is assured.

The test consists of bringing the aeroplane, for a certain position of the engine throttle, in a series of static conditions (straight flight) and measuring the relation of indicated speed with elevator position. In England some tests of this kind were made in 1919.* In Holland, Dr. H. J. van der Maas made exhaustive measurements of this sort.† Interesting tests on longitudinal control and stability were made by Mr. W. H. Hübner of the D.V.L. (German institute for aeronautical research).‡ A few of their results are shown.

* Reports and Memoranda No. 636, S. B. Gates. Control as a Criterion of Longitudinal Stability. R. & M. No. 638, H. Glauert. The Longitudinal Control of an aeroplane.

† Part V. Verslagen en Verhandelingen van den Rijksstudiedienst voor de Luchtvaart, Amsterdam, 1929. National Institute for Aeronautical Research.

‡ Fifth Congress for Aerial Navigation, The Hague, 1930, p. 390.

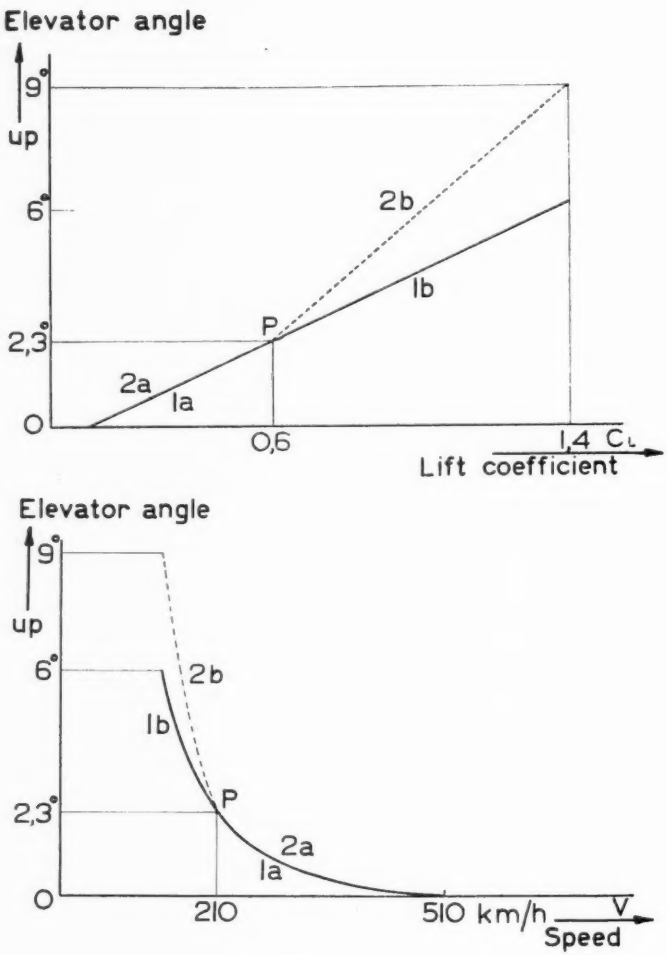


FIG. 1.

*Elevator angle versus lift coefficient (top).*
*Elevator angle versus speed (bottom).*

In the first place I want to draw attention to the method of plotting. For direct work it seems practical to plot the elevator angles found against the indicated speeds. However, from a more general standpoint it is easy to see that it is better to plot elevator position against lift coefficient. In most cases we find with the latter method a curve which is practically linear. This is not astonishing, as a number of aerodynamic quantities, on which the equilibrium depends, are linear functions of the lift coefficient. With the object of showing the difference in character of the curves in the two types of plottings, Fig. 1 was prepared. Apart from a straight line, there is a line with a kink (2). The discontinuity in the corresponding curve 2 is almost lost in the lower figure where the elevator angle is plotted against speed.

Fig. 2 is a result of tests of Mr. van der Maas, the other figures represent Mr. Hübner's results found with the Junkers F 13 monoplane. It has been found that the slope of the $B - C_L$ curve varies with engine throttle and with position of centre of gravity. The more backward the centre of gravity, the less the slope and the less the longitudinal stability. Of this latter fact Mr. Mervyn O'Gorman was aware already in 1913 with respect to full-scale tests made at Farnborough.* Mr. Hübner shows that the curves intersect at zero lift (Fig. 3). For different centres of gravity the slopes are a linear function of distance of centre of gravity from the leading edge of the wing (Fig. 4). The shifting of the centre of gravity forward corresponds with applying a pitching moment which can be balanced by an elevator movement. Thus the action of

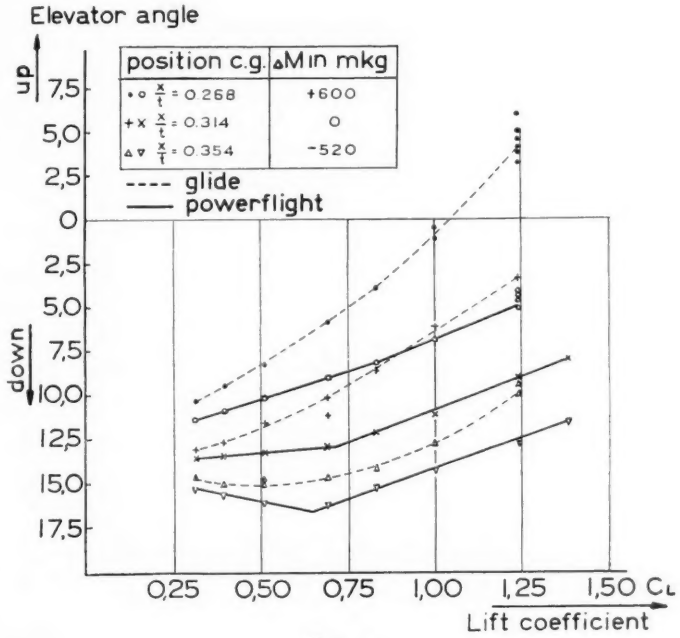


FIG. 2.

*Elevator angle versus lift coefficient for engine, on and off, three positions of centre of gravity.*

the elevator is measured, and the curve of moment coefficient as a function of lift coefficient for different locations of the centre of gravity may be deduced. From his experiments Hübner was able to draw the Fig. 4, in which the slope of control curve ($dB/dC_L$) and the stability coefficient, *i.e.*, slope of the moment curve ($dC_m/dC_L$) are plotted against location of centre of gravity.

The stability is greatest for engine off. The centre of gravity may be further back with the engine off than with the engine on before the stability becomes zero. It is seen that the two different slopes become zero for the same location of c.g. Mr. Hübner also measured the longitudinal force applied to the elevator control. Results are plotted against the corresponding dynamic pressure ($q$). In Fig. 5 the results are shown for three different positions of c.g. The experimental values lie on straight lines. The slope ($dP/dq$) decreases with shifting

* Reports and Memoranda 134. Longitudinal Stability.

backward of the centre of gravity (compare Fig. 6). With engine on and most rearward c.g. the control force slope is negative (vide Fig. 5 below). Fig. 6 shows that the control force slope (control force stability) is proportional to the slope of moments (aeroplane static stability).

It may be mentioned that the control forces also depend on the balance of the masses of the elevator control system. With regard to the prevention of flutter

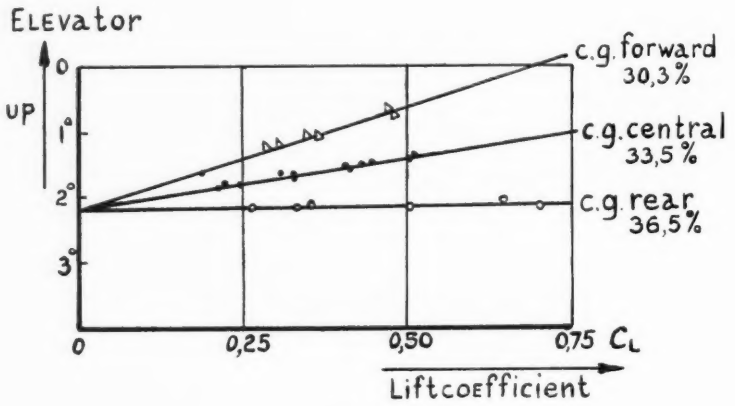


Fig. 3.

*Elevator angle versus lift coefficient, three positions of centre of gravity. With c.g. at rear; slope and stability zero.*

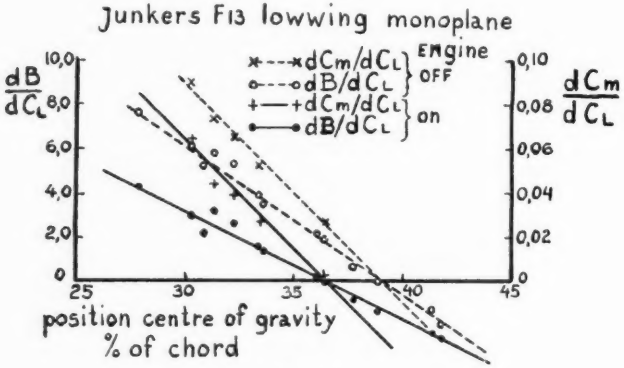


Fig. 4.

*Slope of curves of elevator angle and of pitching moment as functions of position of centre of gravity.*

of the elevator, this control surface should not have its centre of gravity behind its hinge axis, a fact which seems to diminish longitudinal stability with controls free.

The measurement of control forces during all test conditions seems to be of little interest. Friction, which is rather appreciable with a new machine when type tested, may decrease within a year's service.

With regard to the question raised by Professor Hill in his paper about control forces varying with control position, I may add that I believe—and this opinion was backed by a physiologist—that we are more masters over our movements if we feel a reaction opposite to the movement, a condition which is called " to have feeling." This leads me to say that piloting errors will be greater when the control forces almost disappear.

I want to draw attention to another point which refers to anomalies in the control position curves. In some cases the curve shows an increase of upward

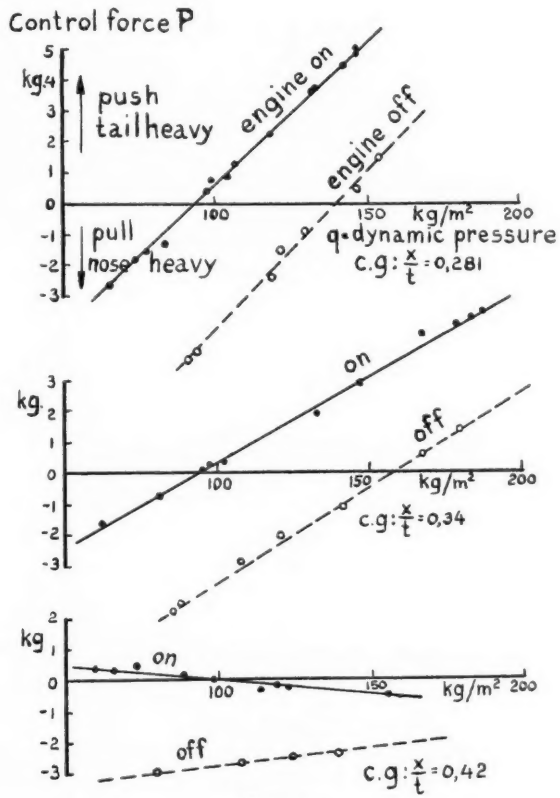


FIG. 5.

*Force on control column as a function of the dynamic pressure (q), for three positions of c.g.*

movement of the elevator at high lift values. This indicates that the downwash of the wing in which the tailplane lies is no longer increasing proportionally with the lift. This may be due to separation of the flow from the central part of the wing (relatively upwash). The elevator curve thus gives an indication of the desire for gradual central separation, a phenomenon which usually leads to nice symmetrical stalling characteristics. In cases of spoiled airflow due to protuberances on or leakage through the wing, separation of flow may occur at a relatively small lift coefficient (say 0.6). This will also induce a discontinuity in the control curve (compare Fig. 1). Sometimes an irregularity is found in a

curve which otherwise is a smooth one. Such discontinuities, sometimes amounting to one degree of elevator angle, may be caused by the horizontal tailplane passing through the wake produced by the wing. It was found in such cases that it was very difficult to keep the aeroplane for some time in this position.

I conclude that the curve of elevator positions plotted on $C_L$ is very useful for estimating the longitudinal stability, and above that, it will in many cases give valuable information with regard to some aerodynamic characteristics of the aeroplane.

The measurement of the control position may be done with a recording apparatus. This was done by several investigators, *e.g.*, Capt. G. T. R. Hill on a Bristol Fighter.*

In this report it is stated that the slope of the control position curves showed that the aeroplane was just unstable with elevator fixed.

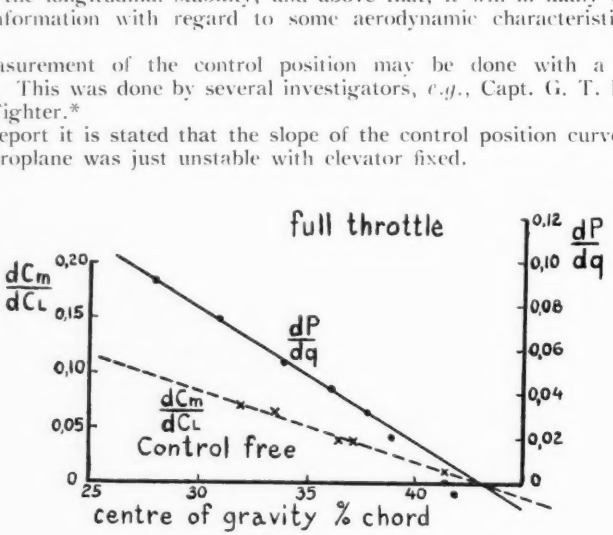


FIG. 6.

*Slope of curves of control force and of pitching moment as functions of c.g. position.*

Practically all type tests in Holland have been performed with the aid of small indicators from which a thin string was attached to the control in the vicinity of the pilot and of the observer. At one time I devised a clock-type indicator (Fig. 7, at bottom right). Recently I applied another simple instrument on which it is easier to read the figure directly (Fig. 8). For use with all controls, at the same time, the triple instrument is used (Fig. 9). This instrument has been used in an automatic observer in which the instruments are simultaneously cine-photographed (Fig. 10, automatic observer).

§ 1*b* refers to the sideslip, a rectilinear asymmetrical flight. This test shows us whether there is positive weathercock stability, and whether the rolling couple due to sideslip ($L_v$) has a restoring tendency.

The control positions of rudder and aileron are read for a series of banks, say bubble readings of $-30$ (left), $-10$, 0, $+10$ and $+30$ (right) degrees. If the yawing moment, due to the aileron angle is negligible, the rudder angle compensates the yawing moment of the aeroplane due to sideslip. If the aeroplane is directionally stable, it tends to yaw towards the low side and the higher side of the rudder bar has to be pushed forward.

I will not say that this test is sufficiently accurate for measuring the directional stability for small angles of yaw, which is important for knowing the characteristics when flying a straight course. This may be done by locking the rudder for this condition.

* Reports and Memoranda 1060, 1927. Flying positions of control surfaces of the Bristol Fighter.

For the desired direction of the rolling moment due to sideslip the control column should be pushed towards the lower wing. I need not say how astonished I once was to fly a glider in which one had to prevent the wing continuing to drop during the sideslip, thus demonstrating negative rolling stability. A small dihedral angle was sufficient to correct the stability.

The forces are measured or estimated. These forces are an indication for lightness of control.

In order to limit the number of tests and thus the hours to be flown, the asymmetrical cases are tried at two basic speeds, one high and one low. For these speeds cruising speed and the speed of best climb are chosen. When high lift devices are present a still lower speed is also chosen, this one being about 20 per cent. higher than the minimum speed.

§1*c* deals with steady turns. The positions of the three controls are read for left- and right-hand turns with little and steep bank without sideslip. The control forces are estimated.

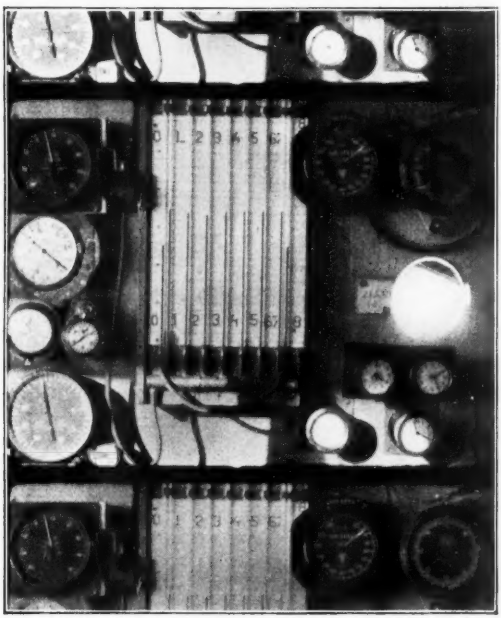

FIG. 7.
*Instrument panel, at right hand bottom three control position "clocks."*

Abnormal conduct in turns, too great opposite aileron, extravagant control forces, *e.g.*, on the rudder, etc., may thus be found.

§1*d*. When the control positions are patiently studied for steady turns (§1*c*) the three controls are kept in place, or better, locked and then the movement of the aeroplane is studied; preferably the bank is read on the artificial horizon at intervals of 5 or 10 seconds for checking whether the bank increases, and if so, at what rate. If this rate is small, say 10 degrees in 30 seconds, this spiral instability will do no harm.

§1*c*. This test gives an impression of the reaction of the aeroplane when a given force acts on the elevator control. The test is only done for a few speeds, *e.g.*, the basic speeds mentioned above. The control force of 5 or 10 pounds is applied by hand with a small spring balance.

§2*a*. This test is a check on dynamic longitudinal stability. A disturbance is given by the elevator from a position of equilibrium at a basic speed, the speed is increased or decreased and the elevator again held fixed or locked in the position of equilibrium. The oscillation is followed or recorded.

This sort of test has often been done in English investigations of stability. In most aeroplanes the oscillations are strongly damped within the normal range of flight.

§2*b*. Is a test similar to the former. It is intended as a check on the weather-cock stability by kicking the rudder. However, due to yawing speed and rolling movements, it is a check on the lateral stability. Aeroplanes with moderate dihedral angle show a yawing and rolling movement with the ailerons locked. When the dihedral angle is great, the aeroplane increases its rolling and dives.

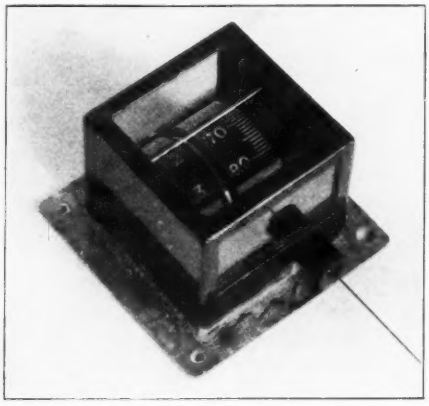

FIG. 8.
*Control position indicator.*

§3. These tests show us the lateral controllability, in part *a* when all controls are used normally, and in part *b* and *c* when certain errors of control are made. Thus we learn what margin of safety is present with regard to the misuse of ailerons and rudder.

Test 3*c* sometimes gives interesting results: It shows the influence of the yawing moment due to the ailerons. Quick movements as a rule are at first followed by an opposite yawing, as revealed by the turn indicator. Modern machines will soon after go into the normal turn. Coming out of the turn only by the ailerons is more difficult.

§4. These tests deal with the effect on the aeroplane of throttling the engine or opening the throttle when gliding. In some aeroplanes the influence is rather great, so that the pilot has to watch the controls carefully in order to prevent unsafe movements of the aeroplane.

In test *a* the influence on the longitudinal equilibrium is observed. If the elevator curves for engine on and off show appreciable differences in the diagram, as shown in Fig. 2, there will be a great change in speed when the elevator is locked before the throttle position is altered. In the Dutch requirement it is

desired that the speed should not increase to more than 1.2, the highest speed (in horizontal flight) with hands off. This requirement is partly based on the assumption that longitudinal control should be possible, in case of emergency, by the engine throttle. Since trimming tabs on the elevator are being generally used, this sort of longitudinal control seems no longer necessary in cases when the elevator control unit is defective.

The tests mentioned in §4*b* are becoming of increasing importance since multi-engined machines with side engines are coming into general use. Excessive yawing motions or abnormal high loads on the rudder control should not occur if a wing engine is suddenly stopped.

The rudder force of a certain aeroplane increased up to 200lbs. when one outboard engine was quickly stopped. This was due to the yawing movement which gave a lateral inflow on the rudder. The rudder seemed to be aerodynamically balanced by the servo tab (of Flettner type). However, the rudder axis lying at the front of the rudder, this tab only assists in giving rudder from the symmetrical position, but does not balance the rudder for lateral inflow. It was found that this aeroplane, after gaining a yawing speed of about 5 degrees per second, dropped a wing accompanied by loss of height.

Tests on the conduct of an aeroplane, when one or all outboard engines are cut out at one side, are of great importance with regard to the safety of the take-off.

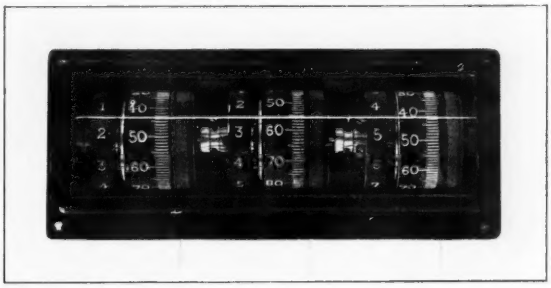

FIG. 9.
*Triple control position indicator.*

Though the hazard of stopping of the engines on one side is not so great, the consequences of such an accident may be disastrous if the speed of flight is so low that the aeroplane is not fully controllable.

In a study on the safety of the take-off, Mr. P. de Winter and I emphasised the necessity of keeping the aeroplane low after taking-off so long as the speed has not passed the safe limit, *i.e.*, so long as the aeroplane is still in the "vulnerable range of speeds." The flight of a multi-engined aeroplane is called vulnerable when the control forces get excessive, the rolling stability may be lost, or the wing be stalled when one or more engines stop abruptly. This condition of keeping the aeroplane low after take-off, of course, lengthens the necessary take-off run and thus increases the dimensions of the aerodrome, a consequence which is inevitable for safe flying.

This requirement relates to the following, which deals with stalling, especially because the stalling speed with engines on is often much lower than the stalling speed with engines off. If the aeroplane climbs at a speed which is just above the stalling speed with engines on, the condition is vulnerable, with respect to stalling, which will happen if one or more engines stop.

§5. *Stalling.*—Apart from the case mentioned above (stopping of an engine), stalling must be considered as an error of control. When we say this, we only refer to aeroplanes of the non-acrobatic category.

The Dutch requirements are not so complete as the British ones, though in some respects they go further. As a complement to the questions 11*b* of our Test Procedure, we have inserted the British Tests on stalling (*vide* Appendix I). By the courtesy of Mr. K. T. Spencer, of the British Air Ministry, I am able to add in Appendix II a summary of the reports of test pilots for six British aeroplanes.

These reports give a complete statement of the behaviour of the aeroplanes at the stall from straight flight and in turns. However, we feel that some more precise data might have been obtained when some instruments, control position indicators or recording instruments have been fitted—still without going so far as to start a thorough research on stalling.

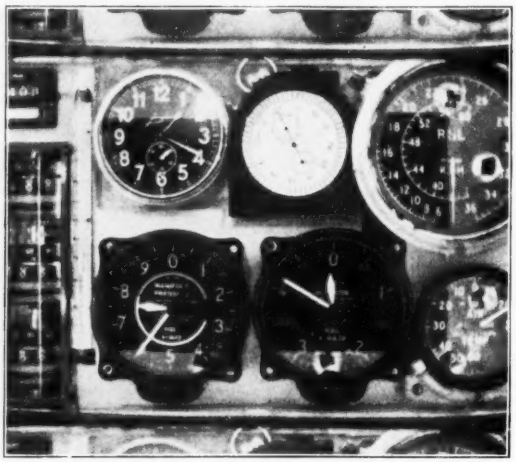

FIG. 10.

*Instruments of N.L.L. automatic observer.*

The Dutch requirements (Art. 11*b*) prescribe in general that aeroplanes will continue straight gliding flight with the control column fully back and the other controls kept central.

It has been found that some aeroplanes, which were on the market, could not fulfil this requirement. The requirement was altered so that heavier machines were accepted if they gave an adequate warning before they are stalled. The tests are described in the test procedure.

With the object of giving the necessary information with regard to the "vulnerable range of speeds," the stalling is also tested with engines on. Movements of aeroplane are observed or recorded, in addition to stating what is the minimum loss of height for recovery from the stall.

The control position, especially of the elevator, is measured when the loss of rolling or of longitudinal stability sets in. The elevator position may be expressed in terms of the total possible displacement of the control column (say 10 per cent. from the rearward position).

As a general remark I want to observe that aeroplanes show different ways of stalling. In the symmetrical class we see in the first place the nice descent

with nose high up and control column fully back, some shivering being observed due to the separation of flow on a small central part of the wing.

The second symmetrical stalling is more frequent. In that case the nose drops gently or violently, which is supposed to be caused by the more or less sudden separation of flow from the wing, which may also give an upwash to the tail with diving following.

In the asymmetrical class we see wing-dropping, which in some cases is limited to about 45 degrees, accompanied by some yaw and steep diving; the aeroplane getting soon under control again. This diving seems to help in reducing the mean angle of incidence of the aeroplane and thus unstalling the low wing. The violent type of wing-dropping is followed by the incipient spin.

In one case I observed a moderate dropping of one wing, immediately followed by the dropping of the opposite wing and falling into the spin.

With the object of complying with the non-stalling requirements, it is obvious that great attention should be given to the backward limit of the centre of gravity. In several transport planes a librascope is rigidly fixed in the machine.

Many tests have been made by Dr. van der Maas for acquiring non-stalling characteristics by limiting the upward movement of the elevator.

Though useful in many cases, it is impossible in other cases to apply this measure for safety, as the landing with tail down is rendered too difficult, if not made impossible. I now touch a point mentioned by Professor Hill in his December paper. This is due to the ground interference, which produces a diving couple and increases the longitudinal stability when the aeroplane flies near the ground. In one respect this ground effect may be usefully applied to obtain an indication of ground proximity in cases of bad visibility. On the other hand, I consider that the downwash at the centre of the wing may be diminished before the landing, such that the ground will not appreciably affect the tailplane. If this goal could be reached, the elevator movement on non-acrobatic aeroplanes could be limited such that non-stalling would be coupled with ease of landing. In addition this limitation can be coupled to the wing-flaps and to the engine throttle for increasing the safety. This measure of rendering the aeroplane safe with respect to stalling might also be applied to service and other acrobatic aeroplanes by coupling a movable stop of the elevator with a "landing lever," which in many aeroplanes may be interconnected to the mechanism for lowering the undercarriage or the wing-flaps. I suppose that in this way the danger due to stalling at low height, and thus the damage to personnel and material, may be appreciably reduced.

Incidentally, I can add that on a small Dutch touring plane the elevator stop consists of a rubber block, rendering full tail down landing possible, but still warning the pilot, by the increase of the pull on the stick, that he approaches the limit of safety.

I may mention that the natural aerodynamic warning consists of buffeting, sometimes mild at the beginning and violent when still increasing the angle of incidence. In one case the K.L.M. (Royal Dutch Airlines) managed to obtain a warning by simply putting an open tube above the wing tip near the rear spar at less than two inches from the surface. When the boundary layer increases in thickness, before important separation of flow occurs, so that the tube no longer has an undisturbed total head, a pressure element gives the warning. This was tried before the N.A.C.A. device, in which a spoiler ridge is used, was known in Holland.

I firmly believe that loss of lateral stability due to stalling will in future be overcome, and even that stalling of aeroplanes will vanish as a source of danger by continuing systematic and simple aerodynamic research in flight.

§6. In this section we deal with several miscellaneous items.

The behaviour of the automatic pilot has to be checked. One of the safety requirements states that the pilot should be able to master this mechanical aid

in cases of emergency, among which I count partial breakdown of the robot. The control of aeroplanes is also tested with feathering propellers and with other devices.

I fear that I have told you very little which was not known to my British colleagues. I only hope that I may have supported the opinion that a complete and systematic series of simple tests will teach us much about the characteristics of a new type of aeroplane. We thus hope to acquire the safety which is necessary for obtaining public confidence in flying. To those who object to exhaustive flying tests I want to say, that the couple of hours necessary for testing a prototype is negligible, not only with respect to the hours to be flown with all the machines of the type, but also with respect to the hours which one aeroplane of the type will fly in a year.

## Appendix.

### Airworthiness Board for Civil Aircraft.

### Test Procedure.

### Testing Stability and Control.

#### Introduction.

This test procedure gives a translation of the Dutch Civil requirements, and also questions and remarks which help the test pilot in applying these requirements by giving more or less sharply defined questions.

In these questions certain limitations have been given. Without these limitations the field of testing would be too wide as there are so many variables, which may affect stability and control of modern aeroplanes.

#### Basic Speeds.

For tests in which the conditions and movement are unsymmetrical the speeds which define the angle of attack, *i.e.*, the condition in the plane of symmetry, are limited only to two values.

*The highest basic speed* is defined as the cruising speed, which is often defined by the maker, otherwise it is defined as the horizontal speed at cruising altitude at 65 per cent. of rated power.

*The lowest basic speed* is the speed for best climb (landing flaps and undercarriage in).

#### Records and Reports.

The test reports must be preceded by :—

1. Tabular description of the type of aeroplane, showing the complete geometrical data with regard to linear dimensions, surfaces of wings, stabilising and control surfaces, also dimensions of tyres, attitude of fuselage, setting of wings and control surfaces (in extreme positions), etc.

   The weight of the loads for different centre of gravity positions.

   Data on engines and propellers.
2. Description of the principal equipment.
3. The performance data.
4. Every report *shall be signed* by the chief of the testing department, as well as by the pilot and the observer(s) acting during the tests.

   In landing and take-off tests the date will be mentioned and also the condition of the ground.

Apart from answering the questions mentioned in the test procedure, it is requested to complete the answers by giving additional remarks relating the impressions obtained by the men responsible for the tests.

Complete answers of the questions will render duplication of tests superfluous.

Fixing controls by hand is uncertain and takes too much time. Automatic pilots allow fixing one or more controls without difficulty.

Unsteady movements are difficult to observe and describe completely unless cinematographic records are made. For this purpose the so-called automatic observer improves speed and quality of observation. Still the addition of personal observations by experienced observers may complete and correlate the justification of the conclusions.

AIRWORTHINESS BOARD FOR CIVIL AIRCRAFT.

THE SECRETARY,

(Signed) P. DE WINTER.

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| Dutch Requirements Decree 471 II<br>Translation.<br>Revised 23/1/39. | Remarks and questions. |
|---|---|
| Take-off and landing. | |
| 3. *General.* | |
| (1) The requirements mentioned in the following articles shall be met on an aerodrome of which the condition can be considered as normal and at a wind velocity of 2.5 m./sec. (=9 km./h. =5.6 m.p.h.) or less, measured at a height of 3 m. (=10ft.) above the ground. The landing run is measured along the path of the aeroplane on the ground from the point where the wheels touch the ground for the first time to the point where the aeroplane comes to rest. | A normal aerodrome is considered to be one with grass surface, not hard, dry, nor very wet, the grass having a length of about 10 cm. 4in. or concrete or tarmac (coefficient of ground friction 0.05) air pressure 760 mm. Hg. =29.92in., air temperature 15 Centigrades.<br>*Questions.*<br>(1) Has ground friction been measured? How?<br>(2) On what sort of ground surface are tests made?<br>(3) How is wind velocity measured? |
| (2) When during the tests the condition of the air is not the normal one or when the velocity of the wind is not equal to 2.5 m./sec. (=5.6 m.p.h.), the results of the tests are corrected to those, which would be found at the normal condition of the air and a wind velocity of 2.5 m./sec., unless the differences are greater than those which may be considered allowable in connection with the reliability of the method of correction. | *Questions.*<br>(1) What differences have been encountered in wind speed, atmospheric pressure and temperature, ground friction, etc.<br>(2) What method for correction was applied? (Give exact reference of book or report.) |
| 4. *Take-off.* | |
| (1) When flying in a straight line after leaving the ground, the fully loaded aeroplane must have reached an altitude of at least 20 m. (=65.6ft.) at a distance of 600 m. (=1,970ft.) from the point at which the aeroplane starts from rest and shall continue its climb after that. The next part of the flight path shall have an inclination of at least 7 per cent., whilst an altitude of at least 220 m. (=722ft.) shall be reached, within 3 minutes after leaving the ground. | *Remarks.*<br>The proof of fulfilment of this requirement may be given by calculation of the results obtained during level take off CKL diagram (acceleration versus speed). Vide: Beschorwing veiligheid start = considerations on the safety of the take-off, Nov. '38.<br>*Questions.*<br>(1) Are rated engine values for taking off obtained during take-offs (intake pressure, revs.)?<br>(2) How is height measured after take-off?<br>(3) What was height at 1,970ft. from rest? |

TEST PROCEDURE—(*continued*).

| Dutch Requirements Decree 471 II Translation. Revised 23/1/39. | Remarks and questions. |
|---|---|
| Generally the engines shall not exceed the international power and the international number of revs. during this climb. In particular cases an exception to this rule will be allowed. However, in no case shall the engine be loaded more unfavourably than it has been during the type tests. | (4) What speeds at take-off and passing 1,970ft.?<br>(5) What is height after 3 min. climb?<br>(6) At what height is climbing speed 1.64ft./sec. or = 98.5 per min. (service ceiling) on all engines working or one or more throttled back?<br>(7) At what height is climbing speed zero (absolute ceiling) on all engines working or one or more throttled back.<br>All engines working. |
| (2) The fully loaded aeroplane shall have an absolute ceiling of at least 2,000 m. (=6,562ft.), unless the aeroplane will be used only in the Kingdom. In that case a statement will be made on the Certificate of Airworthiness. | Last case of no interest here. |
| 5. *Landing.*<br>The landing run of the fully loaded aeroplane shall not be longer than 250 m. (=820ft.), for aeroplanes, the maximum permissible all-up weights of which are less than 5,000 kg. (=11,023lbs.) or 300 m. (=984ft.) for aeroplanes having maximum permissible all-up weights of 5,000 kg. (=11,023lbs.) or more. For meeting these requirements brakes may be used, if necessary. During these tests the engine(s) will be throttled down at an altitude of at least 40 m. (=131.2ft.) above the ground and a rectilinear flight will be commenced. | *Questions.*<br>(1) How long is the landing run?<br>(2) What kind of aerodrome?<br>(3) What was the speed at contact with ground?<br>(4) What engine speed during final glide and during run?<br>(5) What was wind speed?<br>*Remark.*<br>The question on engine revs. relates to influence of propellers on lift and drag. |
| SECTION III STABILITY—CONTROLLABILITY AND CONTROL FORCES. | |
| 6. Aeroplanes shall be stable with respect to the three principal axes in all possible flying conditions and easily controllable. | This general requirement is dealt with in detail in the following ones. |
| 7. (1) The controllability of the aeroplane shall be such that in normal rectilinear flight, while the engine controls remain unchanged, the position of the elevator trailing edge at high speed is lower and at low speed higher than it is at average speed. | *Questions.*<br>(1) Control positions should be measured for extreme forward and rearward positions of C.G. and at different throttle and flap settings. Throttle setting at least for maximum endurance power and throttle back; at least flaps up and flaps down.<br>(2) Control positions plotted on lift coefficient (at least 7 values, for each condition).<br>(*a*) Are curves nearly straight? Are there kinks?<br>(*b*) What is slope (mean value in each case)?<br>(*c*) Are measurements made of the elasticity of controls (for cases in which the position is measured at the control column and not at the control surface)?<br>(3) What is the difference in stick-position with 10lb. longitudinal control force (forward and rearward), what are the corresponding speeds? The control |

TEST PROCEDURE—(*continued*).

| Dutch Requirements Decree 471 II Translation. Revised 23/1/39. | Remarks and questions. |
|---|---|
| | force is adjusted to zero for the two basic speeds. |
| | *Remark.* The plottings relating to these questions have to be inserted in the test report. |
| (2) In order to assure the balance of the aeroplane during a steady straight side-slip, the ailerons shall be moved into the direction, which would give a lateral inclination to the cross-wind and the rudder into the direction which would give a turning from the crosswind. | *Questions.* (1) What are aileron and rudder positions in left and right slip with 10° bank with engine normal power in horizontal flight and with engines off (also 1 or 2 engines off at speed of best climb and flap up and down with 10° bank and 30° bank or max. bank)? (2) What are approximately the rudder forces when controls set for straight flight at both basic speeds? |
| | *Remark.* For slipping tests control position indicators are also necessary on rudder and aileron control. The control positions should also be read between left and right slip with zero bank. |
| (3) In any position of the aeroplane it shall be possible to correct small changes in the flight path by small control movements, so that the aeroplane cannot get increasing movements, deviating from the flight path. | *Questions.* (1) Are there conditions where the requirement is not fulfilled? (2) Are there conditions, where swinging, rolling, pitching or yawing oscillations occur? (3) Are these movements easily checked by the controls? (4) If these movements occur, describe conditions, magnitude of angular deviations, etc. (5) In sharp turns can bank and rolling movementss be checked, (*a*) By ailerons *only*, without use of rudder? (*b*) By rudder only, without use of ailerons? (6) At stalling attitude do the ailerons remain efficient? Vide p. 7, 11*b*. |
| | *Remark.* The questions 1-5 relate to both basic speeds. |
| (4) When the elevator is moved from the position corresponding to a condition in which the aeroplane is in balance and hereafter is brought back and kept in that position, the amplitude of the oscillatory movement, into which the aeroplane has come, shall not increase, but decrease by itself. | This test is performed at both basic speeds, at the lower speed also with engines off. The speed is increased and decreased by 30 to 20 m.p.h. at least, and then column brought back to position of balance. The indicated speeds are plotted against time, or at least the highest and lowest speeds and the corresponding times. |
| (5) When from steady straight flight a rotation around the vertical axis occurs, the aeroplane shall recover automatically and quietly in a flying position in which it does not slip, when the controls are kept in or moved back to the normal position. | For this test it is preferable to lock elevator and aileron, the position indicator for the rudder being used only. The rudder is pushed such that 20° or 30° bank is indicated. Then, after being shifted to the neutral position, the bank indicator is read at extreme values, also time of complete oscillation. |

TEST PROCEDURE—(*continued*).

| Dutch Requirements Decree 471 II Translation. Revised 23/1/39. | Remarks and questions. |
|---|---|
| | This is performed at 9/10 max. speed, horizontal flight and in glide at speed of best climb flap up and flap down. |
| | *Remark.* |
| (6*a*) It shall be possible to make turns easily, of which the radius shall not be too large, to right and left with engines at full throttle and with power off. | The bank is read on a lateral level.<br>At speed of best climb (or lower) in horizontal turns (sufficient power of all engines and one side engine off):<br>1. Record duration for a full turn (360°), control positions, speed and bank (on gyroscopic horizon) and engine conditions.<br>2. What is rudder force with and without rudder-trim? (P.S. Some planes tend to dive unless high rudder force is exerted.) |
| (6*b*) The aeroplane shall not have a tendency to tighten a correctly flown turn, when the controls are kept in a position suitable for such a turn. | Tests are made at 10° and 30° bank at high and low basic speeds, the latter also with engine off, and also with flaps down. The control positions for steady turns are carefully checked and then the controls locked or kept very rigidly fixed. The increase or decrease of speed and of bank is recorded after each half turn, for measuring the possible degree of spiral instability. |
| | *Remark.* |
| | In several cases the Director of the National Aeronautical Service has waived this requirement in cases of slight spiral instability, where the flying conditions were not endangered. |
| 8. (1) It shall be possible to control the aeroplane without adjustment of trimming devices, stabiliser (tailplane), or fin in all flying conditions met with such as entering, executing and coming out of turns, side-slipping, flying with one engine dead on multi-engined aircraft, etc., and to do all other operations to be performed in the air, such as adjustment of the stabiliser (tailplane), the fin, the tabs, the wing flaps, the landing gear, etc., without excessive control forces even in bumpy weather. | The tests to be made at both basic speeds.<br>(1) What is the difference in speed (with a control force longitudinal of 20lb.) without changing trimming tab position, at low speed also with flap down?<br>(2) If change of speed is excessive, what is control force change for a change of speed of 10 m.p.h. from position of equilibrium?<br>(3) What are the changes in aeroplane attitude in bumpy weather with controls fixed or possibly only aileron freely used?<br>(4) What are changes in attitude, when well controlled?<br>(5) What are the maximum forces (all in bumpy weather, at a high and a low speed)?<br>(6) What is the time required for bringing landing gear and flaps up or down?<br>(7) What are positions of controls when flying with one engine stopped (throttle closed), at the speed of best climb, and 15 m.p.h. faster and slower?<br>(8) What are the control forces in these conditions, control force servo or balance on and off? |
| (2) It shall be possible to check the movement of the aeroplane by reasonable control movements when engine(s) is (are) suddenly switched off during flight. | Speeds: both basic speeds. At the lowest speed also in turn with 30° bank.<br>engine switched off:<br>*a*. all, *b*. one engine (the inside engine in a turn). |

TEST PROCEDURE—(*continued*).

| Dutch Requirements Decree 471 II Translation. Revised 23/1/39. | Remarks and questions. |
|---|---|
| | Question *a*. What are movements when controls are kept fixed (e.g., during three seconds after quick stopping of engine(s))?<br>Question *b*. What are the control movements necessary for reaching the new position of equilibrium? What are the maximum forces? |
| (3) For multi-engined aircraft, it is required that the turning of the aeroplane caused by suddenly switching off one engine during straight flight with any velocity between the minimum and maximum one as well as in turns can be restored easily by moderate movements of the controls. | Vide previous paragraph and<br>(1) What is control force on rudder bar and aileron if both engines on one side are quickly stopped and the controls are kept fixed during the following three seconds?<br>(2) What are the corresponding aeroplane movements (angle of bank, pitch and yaw; speed of rolling, pitching and yawing)?<br>(3) What are the control forces and the time necessary to bring the aeroplane back to straight flight? |
| (4) (*a*) Changing over from full throttle to power off or vice versa shall be possible by reasonable control movements without adjustment of the stabiliser (tailplane) and without excessive control forces, also for different positions of the wing flaps, landing gear, etc.<br>*b*. When the elevator is released during this transition from full throttle to power off or vice versa the aeroplane shall come into a steady condition of flight at which it shall not make involuntary movements and at which the speed shall not be higher than 1.2 times the maximum speed at all loading conditions occurring in practice. | Vide 8 § 2 and § 3.<br>*Questions.*<br>Flying at 9/10 max. speed and normal power, the controls are trimmed, the elevator control is free, the engines are switched (throttled) off.<br>The speed and time are recorded at maxima and minima.<br>With the other controls the aeroplane is kept on an even keel.<br>*Remark.*<br>In some cases the Director of the National Aeronautical Service waived this requirement on the condition that the control position curves render this acceptable and that other means of elevator control (as trimming tabs) are present. |
| 9. When the aeroplane is provided with an automatic pilot particular requirements may be made. | *Questions.*<br>*a*. Flying at both basic speeds on automatic pilot, what does the aeroplane do (diving, rolling, yawing), when engines (or one engine) are (is) switched off abruptly?<br>*b*. What are changes in rates of roll and yaw, when a force of 20lbs. is exerted on elevator or aileron control or on rudder bar (or pedal) when flying at these speeds and the automatic control is in action? |
| 10. For aeroplanes of which the gross weight is less than 2,000 kg. (=4,409lbs.) and which can easily be brought into a spin, the way in which the aeroplane can be recovered will be investigated. It will have to be proved that this is possible without too large a loss of height. | Though certain aeroplanes are heavier than 2,000 kg. (4,409lbs.) the Airworthiness Board is interested to be informed whether these types have been spun and what was drop in height for checking the spin (expressed in ratio of span). |

TEST PROCEDURE—(*continued*).

| Dutch Requirements Decree 471 II Translation. Revised 23/1/39. | Remarks and questions. |
|---|---|
| 11. Commercial aircraft and aircraft of category I, not being commercial aeroplanes, shall meet the following requirements besides those stated heretofore. | |
| (*a*) Controllability. At a speed which is about 10 per cent. lower than the speed which is the most suitable for climbing, it shall be possible to fly the aeroplane with one engine switched off in a straight line without excessive control force. In that flying condition the controls shall be sufficiently powerful to permit flying in disturbed air. Means of reducing the control forces, such as trimming devices, etc., may be used. The angle of the rudder, necessary to fly in a straight line in that flying condition, measured from the neutral position, shall be smaller than 80 per cent. of the total angle available on that side. | This requirement is a complement to art. 8 § 3 and § 4. |
| (*b*) Flying at high angle of attack. Except in the case mentioned hereafter, in straight flight with the engines switched off the aeroplane shall continue in the position obtained by increasing slowly the angle of incidence of the wing(s) by fully moving back the control wheel or control stick, up to or above the angle corresponding with the lowest speed (critical angle of incidence) or the aeroplane shall return automatically to the normal flying position with a smaller angle of attack. In case the flying qualities of commercial aircraft with an allowable gross weight of more than 5,000 kg. are such that the pilot, when increasing the angle of attack, by moving back the control stick or control wheel more to the rear from a considerable rearward position already obtained, observes clearly (e.g., because the control force, the angle of pitch of the aeroplane, or the elevator setting, which is necessary to produce a certain variation of the angle of incidence increases rapidly, or because the aeroplane starts to make characteristic, not dangerous, but warning movements or the pilot is warned sufficiently by an indicator for that purpose) that the angle of attack approaches the critical one and that the chance that the plane will make uncontrollable movements is great, the requirement meant heretofore is not to be fulfilled and the flying qualities at a higher angle of attack need not be tested. | 1. When the elevator control is at its most rearward position with flaps up and with flaps down:<br>(*a*) What movements do the aeroplane make?<br>rolling, diving, yawing.<br>Preferably the changes from normal should be given: bank, yaw and in pitch also loss in height after 1, 2 or 3 seconds, when the controls are kept in a fixed position.<br>(*b*) Can the plane be kept on a level keel by using the ailerons exclusively?<br>(*c*) Can the plane be kept on a level keel by using the rudder exclusively?<br>2. What is the elevator control position (measured from rearmost position) for preventing loss of lateral stability and of aileron control? What is flying speed and speed of descent?<br>3. What is the control position (measured from rearmost position) for preventing loss of lateral control with rudder?<br>What is flying speed and speed of descent?<br>4. Compare elevator positions of former cases with attitude of take-off at a speed 10 per cent. above stalling speed or lowest practical take-off speed, flaps in take-off position, centre of gravity forward.<br>5. What is negative thrust of propellers at the stalling speed of test *a*?<br>6. What is stalling speed and aeroplane behaviour if throttle is sufficient for zero thrust of propellers?<br>The following tests are performed for information regarding the safety of the aeroplane. Satisfactory results are not compulsory. The following observations will be performed both with undercarriage and flaps up and with undercarriage and flaps down. |

TEST PROCEDURE—*(continued)*.

| Dutch Requirements Decree 471 II Translation. Revised 23/1/39. | Remarks and questions. |
|---|---|
| In no case shall excessive lateral or sudden movements of the aeroplane occur during the flights mentioned above; the ailerons and rudder shall remain sufficiently effective. | TEST 1. DETERMINATION OF STALLING SPEED, ETC.<br>The pilot will determine the stalling speed by flying the aeroplane level at best climbing speed, then closing the throttle and moving the control column slowly back making every effort to keep the aeroplane level laterally. A speed will be reached at which control is lost or a minimum speed is reached. This is taken as the stalling speed.<br>The pilot will then trim the aeroplane to glide hands off at 1.2 times stalling speed as found above or as near thereto as the trimming arrangement will allow. He will then give a slight disturbance to the control column and release it to determine the longitudinal stability. The pilot will report:<br>(*a*) What is the longitudinal stability at the trimming speed engines off.<br>(*b*) How far back the control column must be pulled to stall the aeroplane, defined as an approximate proportion of the total movement, and whether much or little force is needed to stall the aeroplane.<br>(*c*) Whether there is any warning of the approach to the stall, either by a special device or by some clear indication, such as vibration or oscillation or by the abnormal attitude of the aeroplane.<br>TEST 2. SLOW GLIDE.<br>The pilot is to glide at 1.1 times stalling speed. He is to report whether the aeroplane keeps on a level keel and a straight path.<br>(*a*) When aileron and rudder are both held fixed; and *whether having been disturbed from such a condition of flight it can be regained by*:<br>(*b*) *Use of the ailerons* only, the rudder being held fixed.<br>(*c*) *Use of the rudder* only, the ailerons being held fixed.<br>(*d*) *Use of* both ailerons and rudder.<br>For (*b*), (*c*), (*d*) the pilot must report the approximate amount of control movement necessary.<br>TEST 3. STRAIGHT STALL.<br>With the aeroplane trimmed as for Test 1, the pilot is to glide at 1.1 times stalling speed and then pull the control column very slowly back as far as possible. He is to report as under Test 2, (*a*), (*b*), (*c*) and (*d*). In addition he is to report whether the aeroplane drops a wing suddenly, and, if so, whether the wing can be raised by use of the ailerons alone, or whether the aeroplane tends to go into a spin.<br>TEST 4. SLOW SPEED TURN.<br>The aeroplane is to be put into a gliding turn with 30° of bank. The pilot will then reduce the speed by pulling the control column slowly back until the minimum speed |

TEST PROCEDURE—(*continued*).

| Dutch Requirements Decree 471 II Translation. Revised 23/1/39. | Remarks and questions. |
|---|---|
| | is reached at which a steady sustained turn at 30° bank can be maintained. He will make a turn through 180° at this speed. He will then apply aileron to bring the aeroplane out of the turn holding the rudder fixed as in the turn. The control column must not be moved forward. Turns must be made both to the right and to the left. The pilot will report:<br>(*a*) The minimum speed of sustained turns, and the conditions which impose the limit.<br>(*b*) The behaviour of the aeroplane in the turn and as it comes out.<br>(*c*) Whether control remains normal.<br>(*d*) What is the position of the control column during the turn.<br>TEST 5. TURN FROM A SLOW GLIDE.<br>The pilot is to glide at 1.1 times stalling speed and then make the normal movements with aileron and rudder to go into a banked turn at 30° at the same time moving the stick so as to keep the airspeed constant. Any tendency to go into a spin is to be checked immediately.<br>The pilot is to report whether:—<br>(*a*) The aeroplane shows any tendency to go into a spin.<br>(*b*) Any difficulty is experienced in checking a tendency to spin.<br>(*c*) Response to controls is normal.<br>TEST 6.<br>The pilot will determine the stalling speed with the engines at rated power, with undercarriage and flaps up in the same manner as described above. |
| 12. (1) Aircraft belonging to category II (acrobatic) shall be built in such a manner that normal acrobatic flights can be executed without particular risks.<br>(2) When the aeroplane is brought into a spin it shall be easily possible to recover it from a six-turn spin into normal flight without too much loss of height. | Acrobatic of no importance here. |
| 13. SPECIAL REQUIREMENTS.<br>(1) In any flying condition, no part of the aeroplane shall show any sign of flutter or buffeting; no appreciable vibration of any part shall occur in any flight condition occurring in practice.<br>(2) Every aeroplane shall be able to make at full load for a duration of one minute an unaccelerated glide with power off and an unaccelerated flight with engines running at max. speed, at a velocity of 85 per cent. of maximum permissible nose dive velocity (art. 9e Beschikking nr. 471 | 1. Have slight vibration or shudder been observed:—<br>(*a*) When wheels lowered at low speed or highest speed allowed?<br>(*b*) When flaps are down?<br>(*c*) During a side slip?<br>(*d*) When engines are out of step?<br>Where is it obtained:—<br>I. In controls?<br>II. In fuselage?<br>III. In tail?<br>2. Have large vibrations, flutter, or buffeting, been observed, what amplitude, where, and how observed? |

(Unless other

SLOW GUIDE.

| Aeroplane. | Flaps and U/C. | Test 2. At 1.1 Times Stalling Speed. | | Test 1 (ii). At 1.2 Times Stal Speed. | |
|---|---|---|---|---|---|
| A | Up | Stable directionally & laterally. | | Stable longt. normal. Unst longt. C.G. aft. | |
| | Down | Ditto | Ditto | Ditto | Ditto |
| B | Up | Neutrally. Stable directionally. Stable laterally. | | Neutrally stable. Longt. C.G. norm Unstable longt. C aft. | |
| | Down | Ditto | Ditto | Unstable longitudin | |
| C (before modification) | Up | Stable directionally & laterally. | | Stable longitudinal | |
| | Down | Ditto | Ditto | Ditto | Ditto |
| C (after modification) | Up and Down | As before modf. | | As before modf. | |
| D | Up | Stable directionally. Just stable laterally. | | Unstable longitudin | |
| | Down | Ditto | Ditto | Stable longt. C normal. Neut. sta longt. C.G. aft. | |
| E | Up | Stable directionally & laterally. | | Stable longitudinall | |
| | Down | Ditto | Ditto | Neutrally stable small disturbances | |
| F | Up | Stable laterally. Swings left, cannot be corrected by aileron alone. | | Not within limits longt. trim adj ment C.G. norma Just stable longt. C aft. | |
| | Down | Ditto | Ditto | Ditto | Ditto |

Abbreviations: U/C = Undercarriage. C.C. = Co
Remark: The

## SUMMARY OF RESULTS OF BRITISH TESTS FOR CONTROL AND STABILITY AT THE STALL.

nless otherwise stated the remarks apply to tests with centre of gravity normal and centre of gravity aft.)

| | STRAIGHT STALL. | | | SLOW SPEED TURNS WITH 30° BANK. | |
|---|---|---|---|---|---|
| est 1 (ii). TIMES STALLING SPEED. | WARNING. | Test 3. AT THE STALL. | RECOVERY. | Test 4. AT MINIMUM SPEED FOR SUSTAINED TURN. | Test 5. FROM GLIDE AT 1.1 TIMES STALLING SPEED. |
| longt. C.G. l. Unstable C.G. aft. | Vibration originating at the tail. | Easy to stall. Stall gentle. Occurs when C.C. is slightly aft of central. Nose drops at the stall. | No change of direction. | Minimum speed R. & L. = 1 VS. Behaviour normal. Recovery easy. | Behaviour normal. |
| Ditto | Ditto Ditto | Ditto Ditto Ditto | Ditto Ditto | Minimum speed R. = 1.1 VS. Minimum speed L. = 1.17 VS. | Behaviour normal, but C.G. aft when about 1.1 to drop and increase speed in going into turn. |
| ly stable. C.G. normal le longt. C.G. | No definite warning other than slight aileron snatch and general vibration. | Easy to stall. Stall occurs before C.C. is right back. Slight forward pressure required with C.G. aft. Either wing drops, quickly followed by loss of elevator control. At normal C.G. either wing can be raised by ailerons alone during a period of partial stalling; with C.G. aft left wing only can be raised. Tends to flick over and spin to right. | Change of direction, depends upon the rapidity with which opposite control is applied. Min. change 5°-10°. | Minimum speed R. = 1.05 VS. C.G. normal 1.14 VS. C.G. aft. Minimum speed L. = 1.05 VS. C.G. normal 1.1 VS. C.G. aft. Behaviour normal. C.G. normal, not so good C.G. aft. Tendency for spin to develop. Most marked C.G. aft. In general the incipient spin occurs suddenly and cannot be checked. | Behaviour similar to that in preceding column. |
| e longitudinally | Warning more definite. Aileron snatch starts earlier. | As for flaps and U/C up, excepting that wing drops more suddenly and loss of elevator control occurs earlier. | Ditto Ditto | Minimum speed R. = 1.1 VS. C.G. normal 1.08 VS. C.G. aft. Minimum speed L. = 1.05 VS. C.G. normal and aft. Remarks as for flaps and U/C up, excepting that with C.G. aft it is extremely difficult to make a sustained turn at constant speed, due to deterioration of longitudinal stability with aft movement of C.G. | Ditto Ditto Ditto |
| longitudinally. | Marked snatch from aileron felt on C.C. just prior to stall. | Not difficult to stall, but definite effort required. Stall occurs before C.C. is right back. Vibration, suggestive of tail buffeting, fore and aft pitching oscillation. Wing drops suddenly, cannot be raised by aileron alone. Control quickly regained as nose drops and speed increases. | Slight change of direction, approx. 5°-10°. | Minimum speed R. & L. = 1.1 VS. Behaviour normal; if speed allowed to drop appreciably tail buffeting and aileron snatch develops. Recovery easy. | Behaviour similar to that in preceding column. No tendency to spin at this speed. |
| Ditto | Ditto Ditto | As for flaps and U/C up, excepting that tendency for wing to drop was less marked. | No change of direction. | Ditto Ditto Ditto | Ditto Ditto Ditto |
| re modf. | Heavy load on C.C. high position of nose. | Heavy vibrations eliminated. Slight shuddering. Left wing drops gently, followed by nose. | As before modf. | | |
| longitudinally | Abnormally high position of nose. | Easy to stall. Stall occurs before C.C. is fully back. Sharp and sudden, nose or a wing drops without definite warning. Either wing can be raised by aileron alone in earlier stages of stall. If C.C. is moved further back, increasing lateral instability overcomes aileron control. Tendency to go into spin, control can be quickly regained by forward movement of C.C. | Change of direction negligible. | Minimum speed R. = 1.09 VS., L. = 1.08 VS. Difficult to keep speed constant during turn, more marked C.G. aft; due to longitudinal instability and somewhat ineffective elevator control. In turns to left C.G. aft, flicks to right if speed falls. In turns to right, tends to flick right at both C.G. positions. Full top rudder required to keep nose up. | Turn to left made without increasing speed on entering turn. Tendency to increase on right-hand turn. Tendency to flick to right if speed is reduced, feeling given that aeroplane would spin. Flick can be stopped by easing C.C. forward and increasing speed. With C.G. aft response to rudder is not good and elevator somewhat ineffective. |
| longt. C.G. . Neut. stable C.G. aft. | No warning other than ineffectiveness of controls. Nose is not markedly high. | Ditto Ditto Ditto | Ditto Ditto | Minimum speed R. & L. = 1.1 VS. As for flaps and U/C up, excepting that it is easier to keep speed constant in the turn. | Ditto Ditto Ditto |
| longitudinally. | Abnormally high position of nose, fore and aft pitching oscillation. | Easy to stall. Stall occurs when C.C. is slightly aft of central. Becomes uncontrollable unless pressure on elevator control is released. Tendency for right wing to drop, not possible to raise wing by aileron alone. Impression given that aeroplane would spin. | Change of direction negligible. | Minimum speed R. = 1.1 VS., L. = 1.08 VS. Behaviour normal during turn and recovery. Tendency to drop nose on R. turns and to come up on L. turns. | Tendency to increase speed as entering R. turns. Response to controls normal. |
| y stable for disturbances. | Ditto Ditto | As for flaps and U/C up, excepting for marked tendency for right wing to drop. | Slight change of direction 5°-10° | Minimum speed R. & L. = 1.08 VS. Other remarks as for flaps and U/C up. | Ditto Ditto Ditto |
| thin limits of trim adjust- C.G. normal. ble longt. C.G. | High position of nose, ineffectiveness of all controls, snatching of aileron control and general vibration. | Easy to stall. Stall occurs when C.C. is slightly aft of central. Either wing, usually the right, drops suddenly and cannot be raised by aileron alone. Tendency to spin. | Change of direction 25°-30°. | Minimum speed R. = 1.18 VS. C. normal 1.23 VS. C.G. aft. Minimum speed L. = 1.06 VS. C.G. normal 1.1 VS. C.G. aft. Behaviour normal, excepting for tendency to unbank from R. turns. Tendency increases if speed is reduced. | In general the turn cannot be made at this speed (see preceding column for min. speed in the turn). The remarks in that column apply. There is no tendency to spin. |
| Ditto | Ditto Ditto | As for flap and U/C up, excepting that wing does not drop quite so suddenly. Tendency to spiral. | Slight change of direction 5°-10° | Minimum speed R. = 1.35 VS. C.G. normal 1.4 VS. C.G. aft. Minimum speed L. = 1.08 VS. C.G. normal 1.13 VS. C.G. aft. | Ditto Ditto Ditto |

. C.C. = Control Column. C.G. = Centre of Gravity. VS = Stalling Speed. R. = Right Hand. L. = Left Hand. Min. = Minimum.

nark: The British Tests are inserted in the Dutch Test Procedure (informative), §11C, after question 6.

operation might involve some of the big firms appointing an assistant, who might be a brilliant junior, with a roving commission in regard to the subject. That had been said before, but it was well to say it again in order to ask the author to express his opinion.

Dr. H. Roxbee Cox (*Fellow*): The paper was going to be particularly useful to him personally, inasmuch as he was engaged in developing a questionnaire for the use of the Air Registration Board's pilots, a matter of considerable complexity. But he was glad to say that, as the result of a quick comparison he had made between the Dutch test procedure and his proposals, he had found that there was a very considerable measure of agreement, which had given him considerable confidence. He had come to the conclusion that we in this country should make more measurements of a quantitative nature, even though we might not be quite certain of their ultimate value. We should make simple measurements such as the author of the paper had mentioned, and we should try to correlate the quantitative data obtained by that means with the opinions obtained from experienced pilots who were flying the machines. That correlation might in the end prove to be extremely valuable.

It would be agreed that stability was always a desirable feature, and he was interested in the degree of stability which an aeroplane ought to have. The suggestion was made in the paper that for blind flying a minimum degree was desirable. Presumably it was suggested that the pilot experienced least strain if the aeroplane was only just a little more than neutrally stable. Another point was that maximum stability tended to the comfort of the passengers. Possibly that was true; but it led to another point which must be recognised, *i.e.*, that the stability requirements for civil and Service aeroplanes were probably very different indeed. He imagined that for certain types of fighting aeroplanes very little stability was desirable. For the bombing aeroplane, as for the civil transport, stability was definitely required; but for civil aeroplanes probably the requirements were different. He had in mind that if a large machine were stable in the climb, with the C.G. aft, it might be found difficult to hold it in the dive. That might be a disadvantage in a Service bomber, though it did not appear to matter in a civil aeroplane. Consequently, he suggested that if stability could be achieved in the flight conditions for which stability was most difficult to obtain, it did not matter very much in a civil aircraft what degree of positive stability there was under other conditions.

Another reference in the paper which interested him particularly was to the effect of mass balancing elevators. The elevator was likely to be mass balanced with the C.G. ahead of the hinge, for the purpose of preventing flutter; and it would seem that the effect of getting the C.G. ahead of the hinge was to diminish longitudinal stability. He invited the author to say a little more about that, because at first sight—and he admitted that he had not thought of it very carefully—it seemed almost a contradiction in terms. He visualised an aeroplane with its fuselage oscillating up and down in bending and the elevator tending to flap, which was a two-dimensional case of flutter, for the prevention of which it would be a good thing to have the C.G. ahead of the hinge. If one considered a rigid aircraft oscillating in pitch as a whole it would seem that the remedy would be the same; but obviously there was more in it, because as the author had implied, the conditions were not the same.

With regard to the test for eliminating stalling by limiting the elevator movement, he said that it might make tail-down landing difficult. But we should not be discouraged by this, because after all we had the tricycle undercarriage, and in the case of an aeroplane with that undercarriage it was not essential to get the tail down.

Finally, he said he had been impressed, as was Professor Bairstow, with the apparent suggestion at the end of the paper that all the quantitative tests which had been mentioned therein could be accomplished in two hours. One hoped sincerely that that was true, and one would like to know exactly what one could

expect to do in two hours, because it was a matter of very great interest to those who had to pay for the test flying.

(*Communicated.*) On further consideration, it appears probable that the lecturer was referring to the adverse effect of *gravity* (not inertia) on static longitudinal stability when elevators were mass balanced and not to the dynamic stability conditions visualised in the foregoing remarks. I should have thought these dynamic conditions needed consideration, however, and that they might indicate mass balance to be desirable.

Squadron Leader H. P. FRASER, A.F.C. (*Associate Fellow*): He supported the suggestion by Dr. Roxbee Cox that we should try to obtain quantitative measurements and to correlate them with the opinions of pilots who carried out tests on aircraft. Whilst he agreed that at first it might be difficult to interpret the quantitative information obtained, he believed that after some time, when we had collected the data and had classified various aeroplanes according to the opinions of the pilots, we might obtain some very useful information. For that reason he had been interested to note that it was the practice in Holland to measure stick force and control position. Although he personally had never had instruments which resembled even remotely those illustrated in the paper, he had on many occasions made measurements with crude instruments of control forces and rates of roll. On one occasion by referring to the data he had collected he was able to show somebody, who was considering the question of control force in connection with irreversible ailerons, that the minimum frictional force the technicians thought permissible was far too high and quite unacceptable from a pilot's point of view. His argument had carried weight and conviction in this case because it was possible to quote figures in place of making the mere dogmatic statement that the force was too great. Moreover, it gave the technical man something to go on. It showed how far wide of the mark he was, and gave him some idea of the figure to which he had to work.

With regard to the stability required for blind flying, he had read the reference in the paper in a rather different way from Dr. Roxbee Cox. He had understood it to mean that the minimum stability that could be accepted was that required to make the aeroplane reasonably easy to fly in blind conditions. He did not think it meant that a low degree of stability was required for blind flying. He was anxious to hear the lecturer's views on this point.

Endorsing the opinion expressed in the paper that we were more the masters over our movements if we felt a reaction opposite to the movement, he emphasised that was very important in flying. If a control was particularly light there was a tendency to over-correct. It was, of course, equally important not to make the control unduly heavy. In fact it was the old story of having to hit off the happy mean. It was in the consideration of such matters as these that quantitative measurement of control forces, rates of roll and pitch, etc., would be useful. In so far as it is possible to calculate control forces in the design shape it might provide sufficient data to give designers a goal to aim at. We must try to put "light responsive and well harmonised controls" in terms of figures if we possibly can.

As to the effect on the trim of the aeroplane of opening and closing the throttle, he said that one of the most unpleasant experiences, particularly when landing, was to find that in order to keep the aeroplane in the desired attitude and to keep the speed reasonably near the desired approach speed, it was necessary to apply excessive force on the control column when the throttle setting was varied.

Discussing the limitation of the elevator movement as a means of preventing stalling on civil aircraft, he said that the objection to this method arising from some aircraft tending to become nose heavy just before touching the ground would disappear with the introduction of nose wheel undercarriage. The tendency to become nose heavy just before reaching the ground might even be an advantage when a nose wheel undercarriage was fitted. It might prevent the pilot making

a landing with the tail too far down and so pitching forward on to the nose wheel with undue severity.

With regard to the actual flying time required for the tests, he had been interested to hear the views expressed. In his experience the time varied enormously. If the aeroplane responded in a definite manner it was possible to go through the tests quickly with a certain knowledge of the behaviour of the aeroplane in each. But a great many aeroplanes were border line cases in many tests, and the tests had to be repeated several times before it was possible to assess the aeroplane's behaviour with any certainty. Two other things influenced the speed with which the test could be completed. One was the rate of climb of the aeroplane, which made a great deal of difference in the time taken between successive tests to reach a safe height. The second was the experience and quickness of perception of the pilot and observer. Work of this nature required infinite patience and a great deal of practice.

Finally, he said he liked the use of the term "vulnerable." It so aptly expresses a condition through which an aeroplane passes just after take-off, and to a less extent (unless the pilot is extremely careless) during the final stages of the landing approach.

(*Communicated.*) Mr. von Baumhauer's paper is indicative of the great efforts that are being made to make aeroplanes safe from the stability and control point of view and to devise ways and means of being able to measure their degree of perfection or imperfection, as the case may be, in this connection.

The prevention of stalling and stability and control at and beyond the stall quite naturally figures prominently in the paper. Arising out of this, a point that needs emphasising is that with increasing wing loadings the difference between the stalling speed and the minimum safe gliding speed is becoming much greater than hitherto. Therefore, although an aircraft may be stable at and beyond the stall a serious accident may result unless the pilot keeps a close watch on his speed. Any warning device should operate well before the stall. But real safety in landing will only be achieved when the aircraft can be brought in well above the vulnerable (see page 345 for a definition of "vulnerable") speed range without overrunning the aerodrome. (This should be stipulated in the airworthiness requirements—a standard aerodrome length and wind conditions would have to be stipulated for this as is done for take-off.) This can only be done with plenty of drag. But, when the wing loading is very high, with a high drag device in operation the aeroplane will still be vulnerable even at full throttle. Therefore it must be possible quickly to get rid of as much drag as possible without altering the lift. This points to the necessity for the development of a quickly variable drag device on aeroplanes with very high wing loadings. The present high drag landing flaps will not be acceptable on such aeroplanes, and so, unless we can produce the quickly variable drag device, we may be forced to accept a cleaner aeroplane during the landing than is really desirable. We may again run into some or all of the difficulties associated with the flat glide; long float distances, need to glide within small limits of speed to prevent excessive float, large speed changes in the glide for comparatively small changes of attitude and the need to glide nearer the stall. It seems that there is much to be gained by the encouragement of a quickly variable drag device no matter what form it may take.

Mr. J. V. Connolly (*Associate Fellow*): He confirmed the lecturer's suggestion that designers did not give very much mathematical consideration to stability. The usual process was to set down the requirements of general performance, to fix the wing area and the general arrangement of the whole aeroplane to allow of the installation of the equipment and the fixing of the centre of gravity, and then the control areas were usually fixed on the basis of personal experience, assisted by the use of control volume. But control volume was a very nebulous sort of thing. It did not give any particular consideration to the shape, aspect ratio, blanketing or disposition of the control surfaces; and over a range of

aeroplanes he had found tail volume and rudder volume figures varying between 0.3 and 0.78 for horizontal tail volume and from 0.07 to 0.25 for the vertical tail volume. That was a very big range, and it did not appear to him, unless one had had a lot of experience on very similar types, that the use of the control volume alone gave a close guide as to the stability in any direction. It was obvious that one could not arrive at the facts accurately by that method. Usually the fin and rudder at least were modified before an aircraft was really satisfactory in flight, and quite a few aeroplanes never did become satisfactory. Sometimes static longitudinal stability was considered by plotting elevator angle against speed or lift coefficient, thus obtaining theoretically the curves which the author had produced from practice. In this work there was the difficulty of assessing the value of the tail plane due to its position and also the true measure of the downwash. Wind tunnel tests were very often of assistance, but at the small scale of those tests there was frequently a bad scale effect. There was a tendency for designers to use a rudder shape which had become the " trade marks " of their firms, without considering that it might be unsuitable from the point of view of spinning, balancing or even of strength. The reason for that unscientific outlook was probably the inability of the chief designer's technical staff to tell him what shape the rudder should be; probably in many cases there had been failure of rudders which the chief designer had been told were correct, but which in fact had been shown to be much worse than those which had been drawn in on the drawing board by the chief draughtsman. In every case where an unusual test result was obtained, it should be investigated and an endeavour should be made to clear the matter up; and the information so obtained should be recorded.

Any flight test results or stability should provide data which could be fitted into a " framework," and to that end the questions asked of pilots and the measurements made should be related to all the major parameters required by the theory. A questionnaire should correlate the measurements made with the geometric characteristics of the aeroplane, because very often, when reading a report after a machine had been tested—it might have been tested for one particular purpose—one found that a relevant parameter was missing; so that the value of the test was practically destroyed due to the lack of some small observation which could easily have been made without extra work, but which had been forgotten because the major purpose of the test was not to find out what was subsequently desired.

In making a questionnaire one was always faced with the difficulty of deciding what questions should be asked, and what questions should be left out. It was quite possible to make a questionnaire so long that it was practically useless, by reason of the time spent on the test and the difficulty of carrying out the whole test in good conditions. If the author could give some idea of the minimum measurements needed for stability research to enable the framework to be built up, it would be extremely interesting.

Most pilots considered that it was practically impossible to judge stick load by hand, and most of them were not prepared to say whether it was 10 or 25lbs. for example. It had been thought that one might make a " pilot calibrator," by means of which the joystick and rudder bar could be connected to an adjustable spring load not in view of the pilot, so that he could be told that he was pushing, for instance, 10lbs.; and then he could probably carry that sense impression in his mind.

Presumably, except where forces were really large in certain manœuvres, stick position was more important than the force. Control movement and the absence of interaction between the controls was becoming more important in blind flying. Pilots were told to control certain blind flying instruments by using certain controls. (The 1, 2, 3, system.) If there was interaction, this became difficult, and each machine would require a new technique. Usually the forces involved were quite light and the movements small—this, as the lecturer mentioned, led

to difficulty on physiological grounds, it was easier to learn to shape things with a chisel than by the use of the feed and traverse screws on a lathe, for example.

Mr. Connolly asked the lecturer if he agreed that specifying the turns by reference to the rate of turn indicator (rate 1 turn rate 2, 3, etc.) measuring stick position and force was a better idea than measuring *angle* of bank which is an external measurement? Very approximately the angle against rate of turn could be written $2 = 15°$, $1 = 30°$, $\frac{1}{2} = 45°$. This gave something like an international standard if the turns were made without sideslip.

If a recording air speed indicator is fitted, the record from this gave the aeroplanes phugoid—and a good idea of the dynamic longitudinal stability. This could be done stick free or stick fixed. Which appeared to the lecturer to be more important? If there was instability in one case and not in the other, the pilot should know of this for a particular machine so that he could let the stick go or hold it as the case may demand.

Loss of height during turns seemed to be a point where danger could easily arise. Presumably this was due to some mild form of instability?

Mr. P. G. Lucas: He urged that, if only because of the difficulty of securing agreement among highly skilled pilots, it was most important that they should be tied down to a very rigid questionnaire. A test pilot was very often faced with grave responsibilities where, owing to production requirements, only one test could be made.

Commenting upon the reference made to a test covering two hours' flying being sufficient to gain the knowledge required concerning stability and control, he said that in his experience first impressions of first flights were liable to be rather misleading, and he believed it was essential that the pilot should be given the opportunity of carrying out at least two or three flights before giving opinions on its stability. Again, very often pilots had great difficulty in assessing stability, owing to the stiffness of the controls. Nowadays, when aircraft possessed fairly big speed ranges, it was necessary that the controls should be very light at low speeds in order that they should be reasonably light at high speeds. Therefore, if there were any stiffness in the controls, very often they would stay where they were put, and if one tried to put them neutral one could not guarantee that they were there.

The stick control instrument mentioned by the author would be very useful if one could rely on its accuracy. In that connection he referred to the statement in the paper that practically all type tests in Holland had been performed with the aid of small indicators from which a thin string was attached to the control in the vicinity of the pilot and the observer. His comment on that was that unless one could guarantee that the controls were free from stretch or elasticity, difficulties might arise, because at high speeds, where controls were heavy and angular movements of the control surfaces small, the control movement recorded might be very much bigger than the actual movements. On the other hand, an instrument of this description has been used by himself to good effect for measuring control movement at or near the stall where coarse application of controls is necessary.

Finally, Mr. Lucas recalled a particular single-seater fighter which was rather unstable, but which was very popular amongst Service pilots; but when it was made stable it had become extremely unpopular amongst certain of the pilots. Therefore, he urged that the degree of stability required depended upon the duties for which the aeroplanes were intended.

Squadron Leader J. F. X. McKenna (*Associate Fellow*): He agreed that the paper and questionnaire represented what one hoped to learn about the aeroplane; unfortunately, there was seldom time to carry out all the tests one would like to do. Stick position indicators were now being fitted, in spite of some natural opposition on the part of the people who wanted to get the job through and therefore did not want to keep aircraft on the ground for fitting extra instruments. It was valuable to have readings showing the forces that had to be applied to

the controls, and he asked for further views from the author concerning control forces and the devices that were used to measure them.

With regard to the view expressed by earlier speakers that pilots should never be allowed to estimate force without confirmation by an instrument, he said that that was true, except that in the case of certain modern aeroplanes he estimated rudder control force by the strength of his right leg, which he had measured as 400lbs. In some aircraft at high speed that strength was fully employed without appreciable result.

There seemed to be great diversion of opinion with regard to the degree of stability required for various duties. It had been said that a single-seater fighter should not have too much stability; but he was not quite sure what was really meant by that. If much stability meant heavy elevator control, then certainly there should not be too much stability; but if it were possible to associate a high degree of stability with a light and effective elevator control he could not see that the increased stability in itself would be disadvantageous.

In a further reference to the vagueness of opinions with regard to the degree of stability necessary, he said he understood that it was finally decided, in connection with a certain Fleet machine, that stability should be sufficient to enable the pilot to let go of the controls long enough for him to blow his nose! He did not know whether any research had been done to find out how much time that occupied.

Mr. VON BAUMHAUER in the first place expressed his gratitude for the great interest displayed in the paper and for the favourable comments made. He also expressed thanks to those who had mentioned co-operation between the Dutch and British authorities and pilots, and said that the continuation of that co-operation was appreciated, for it would be useful to both countries.

Having paid a tribute to Professor Bairstow, whose magnificent work on the stability and control of aeroplanes since 1910 or 1911 had been so ably treated in his work on "Aerodynamics of Aeroplanes," published in 1920, he dealt with questions of stalling. Magnificent work had been done in this country on stability, on the characteristics of the spin and the means of getting out of a spin. It provided a beautiful example of how such intricate and complicated problems could be treated, and he suggested that some such method as that which had been applied so successfully to the investigation of spinning should be applied more and more to the problems of the stability of aeroplanes in normal flight—in turning, and so on. In the spinning wind tunnel we could solve directly the equations of motion of the model and he considered that that was a very useful method of overcoming the mathematical difficulties, which otherwise would have to be dealt with by elaborate computation.

The problem of design for stability was not strictly within the scope of the paper, which was concerned with testing stability and control; he had not dealt in the paper with research on stability and control or design for stability. If he were to omit dealing with it, however, he would be evading a difficulty which he should not try to evade. He did not think it would be possible to measure in every type of aeroplane all the aerodynamic derivatives which it was necessary to know in the calculation of the stability of flight of that aeroplane. But with the known aids to applied aerodynamics we should measure as many derivatives as possible on certain major types of aeroplane. It was worth while to continue the mathematical treatment of the problem with regard to those principal types. It was easy to change the tail planes or to change the position of the tail planes of a prototype; by so doing, it was possible to make corrections of the calculations that were made following the systematic tests on the standard models of the aeroplanes. When designing for stability it was very useful, and it had been done in England as well as in Germany and France—especially for the bigger aeroplanes, which were so expensive to build, to try a flying model of a machine; by adopting such means, much disillusionment or many disappointments concerning the behaviour of the aeroplane subsequently would be avoided. That

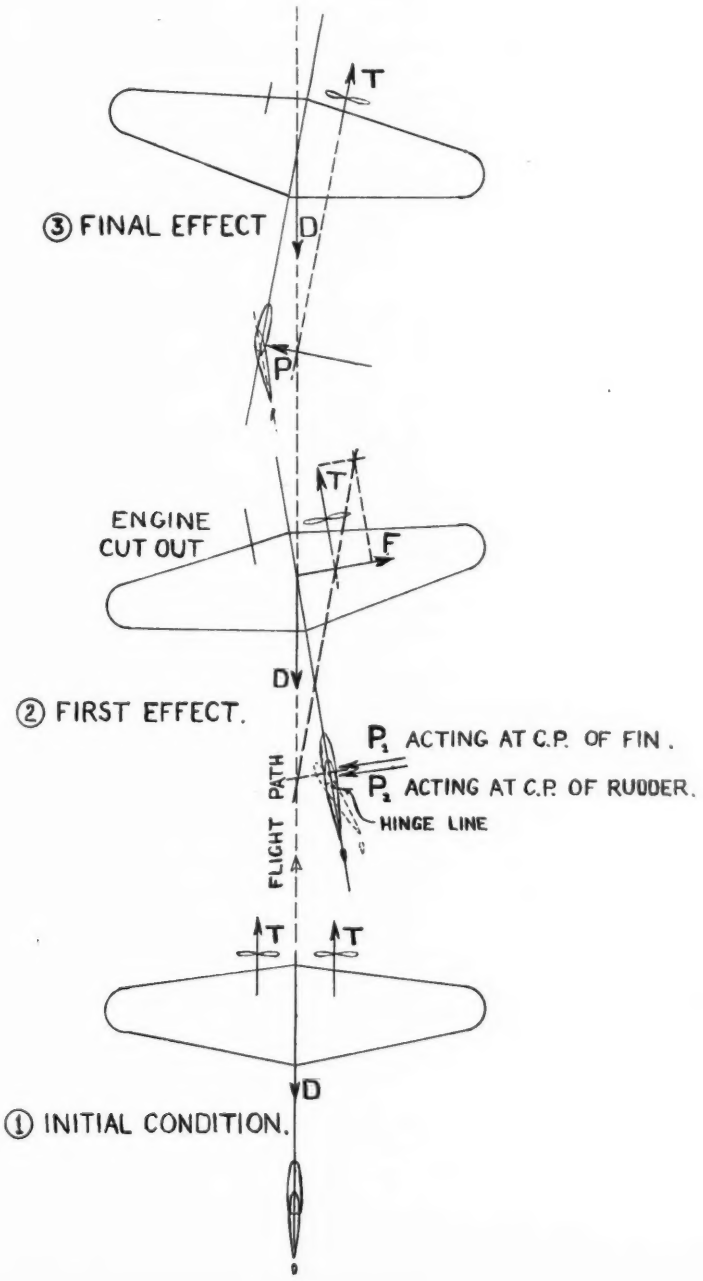
was a question of solving the equations of motion in the air. He had heard it stated by some specialists in England that they tried to suspend a model in the wind tunnel in such a way that certain qualities of stability might be determined from its movement, as, for instance, lateral or longitudinal stability. He hoped that that sort of research would continue and would help the designer to secure the desired stability in his machines.

Dealing with the request for a definition of the minimum quantity of static longitudinal stability desired, he emphasised again that he was concerned with checking aeroplanes from the point of view of safety and not with the measurements of qualities for design. But he had seen in the literature—for example, in the writings of Hübner, in Germany—a figure of 5,000 for the change in moment coefficient per degree of angle of incidence of an aeroplane. In any case, he would check the exact figure, which was acceptable in flight.

With regard to the time occupied in the testing of an aeroplane, he said that he personally had insisted in several cases that all the tests made by the test pilot for the Government should be made within a few hours, or in a couple of hours. He had noted that Professor Bairstow had interpreted a couple of hours as two hours; he was not sure whether that was the normal English practice. However, that interpretation was right. He and a test pilot had tested a twin-engined aeroplane in $1\frac{3}{4}$ hours; in that time they had made all the measurements necessary for the longitudinal stability, the slide slip right and left at different speeds, and so on; they had made turns right and left for perhaps half an hour with 20° and 30° of bank; they had stalled in four different ways (with engines on and with engines off, with the left engine on, then with right engine on, etc.). All that work was done in less than two hours. In the case of bigger machines having wing flaps and other complications, which meant a larger number of variables, the period of testing increased, but the period was not multiplied in exact ratio with the number of variables. Efforts had been made to eliminate certain tests in order to minimise the number of hours flying involved. However, it would be exceptional for an aeroplane to be flown for more than five hours in order to carry out all the tests mentioned in the procedure described in the paper. The testing of some of the bigger machines, such as the four-engined machines which he hoped to see in the United States, would occupy perhaps a long time. But, in any case, within a few days the test would be complete, if the weather was not too bad.

Coming to the question by Mr. Lucas concerning the control position instruments, he said it had been stated that if the controls were elastic, the position of the control column was not a true indication of the elevator. But calibration could be effected simply by moving the elevator and noting what the stick was doing. If the control column were fixed and the elevator could not be moved easily, one had a rough indication of the elasticity. The problem was quite easy, and a workman would occupy not more than one day to fit in strings from the elevator, the strings being pulled by a spring or an elastic cord in such a way as to be a true indication of movement of the elevator. That was not a serious difficulty, and one should not attempt to magnify the difficulties. The total amount of time spent on the testing of an aeroplane was infinitesimal as compared with its flying life.

As to the instruments used for measuring the forces, he admitted that their development had not reached the stage of those used for indicating the positions; but in many cases small spring balances, such as were used in the household, were applied for measuring forces on the control column or the rudder bar. Such spring balances could be obtained for a few shillings. Again, he believed that a very nice instrument had been produced in America for attachment to the rudder bar, indicating at a distance by oil pressure the control forces. For machines having automatic pilots it was possible to use manometers and pressure gauges, which would indicate the pressure in oil cylinders connected to the controls. It


T
③ FINAL EFFECT
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ENGINE
CUT OUT
F
D
② FIRST EFFECT.
P₁ ACTING AT C.P. OF FIN.
P₂ ACTING AT C.P. OF RUDDER.
HINGE LINE
FLIGHT PATH
T
T
D
① INITIAL CONDITION.

FIG. 11.

was quite an easy matter to fit such gauges, and he believed they would be used more and more for testing in the future.

Replying to the President's question concerning the control of the engines in multi-engined aeroplanes, and with regard to the results of the stopping of an engine, he said that if an automatic pilot was used there would be little difficulty when one engine stopped, because the automatic pilot would react very quickly and would apply the necessary rudder force. As to the case in which there was not an automatic pilot, he said there were possibilities of making an instrument which would be such that if the intake pressure or the boost pressure fell off, the trimming tab of the rudder would be moved a certain degree.

On the motion of the President, a very hearty vote of thanks was accorded Mr. von Baumhauer for his most instructive paper and for his masterly handling of the questions put to him.

Mr. H. B. Irving (*Fellow*) (*communicated*): With regard to Mr. Baumhauer's impression (page 334) that designers in this country "do not bother about stability," although that may have been the position fairly recently, I do not think it represents the position to-day; and it certainly will not represent the position as influenced by Mr. Baumhauer's paper. We, in this country, must follow the lead of the Dutch and the Americans, and get down to fitting (at least) control movement and force recorders in our machines in order that assessments of stability may be put on a quantitative basis. I agree with Baumhauer's opinion that the firms' pilots themselves should be called on to make the requisite tests.

With regard to Fig. 2, in which elevator angle is plotted against lift coefficient, I am rather at a loss as to why in certain cases two straight lines of different slopes have been drawn to connect up one series of observations. Why not a continuous curve—not necessarily a very smooth one, but still, a curve? It does not appear probable that any change in slope at such a comparatively low incidence as is represented by the lift coefficient of about 0.65 (where the change of slope occurs) would be absolutely discontinuous as the two straight lines indicate.

I was interested in the aeroplane on p. 345 where, although the rudder was aerodynamically balanced by a servo tab of the Flettner type, it required a force of 200lbs. when one outboard engine was quickly stopped. This would appear to be a case where the external horn balance is advantageous. For a rudder which is anything like closely balanced by an external horn so far as rudder hinge moment at a given angle of yaw of the aeroplane is concerned is generally overbalanced in respect of variation of yaw of the aeroplane as a whole.

Thus, when the aeroplane yaws to port—as it will do initially when, say, the port engine is suddenly cut out—the rudder will automatically tend to set itself against the yaw (see Fig. 11 (2)). In the final steady state to which the aeroplane settles down, however (see Fig. 11 (3)), it is yawing to starboard and the servo would now be helping the rudder over to its proper position while the horn would be opposing. But the emergency of the engine cutting out would be over and the aeroplane would presumably be trimmed directionally by the trimmer. We see then that, while the servo tab makes it more difficult for the pilot to correct quickly for the effect of an engine cutting out, the horn helps him.

Following the lecture the President, Mr. A. H. R. Fedden, M.B.E., D.Sc., M.I.A.E., M.S.A.E., F.R.Ae.S., gave a dinner in honour of Mr. Baumhauer at which the following were present:—

Mr. A. G. von Baumhauer, F.R.Ae.S.
Mr. S. Camm, F.R.Ae.S.
Mr. H. Roxbee Cox, F.R.Ae.S.
Dr. G. P. Douglas, A.F.R.Ae.S.
Mr. A. H. R. Fedden, M.B.E., D.Sc., M.I.A.E., M.S.A.E., F.R.Ae.S.

Squadron Leader H. P. Fraser, A.F.R.Ae.S.
Mr. J. A. G. Haslam, A.F.R.Ae.S.
Mr. J. E. Hodgson, Hon. F.R.Ae.S.
Mr. H. B. Irving, F.R.Ae.S.
Mr. F. Handley Page, F.R.Ae.S.
Dr. N. A. V. Piercy, F.R.Ae.S.
Captain J. Laurence Pritchard, Hon. F.R.Ae.S.
Mr. E. F. Relf, F.R.Ae.S.
Lord Sempill, F.R.Ae.S.
Mr. A. N. D. Smith, F.C.A.
Mr. H. L. Stevens, F.R.Ae.S.
Dr. H. C. H. Townend, F.R.Ae.S.

# ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

*Issued by the*
*Directorates of Scientific Research and Technical Development, Air Ministry.*
*(Prepared by R.T.P.)*

No. 66. April, 1939.

*Penetration of Bombs.* (Engineering Precautions Air Raid Committee Memorandum, No. 2, J. Inst. Civ. Eng., Vol 11, No. 5, March, 1939, pp. 30-44.) (66/1 Great Britain.)

The penetration of a bomb depends on—

1. The velocity of impact.
2. The sectional density of the bomb (lb./sq. in.).
3. The shape of bomb.
4. Nature of material penetrated.

The velocity of impact itself is a function of the height of drop and the sectional density. This density may vary from 0.5 (small incendiary bombs) to 15 lb./sq. in. for large heavy case bombs.

The following table gives representative values:—

| Type of Bomb. | Height of fall (feet). | Impact velocity (feet/sec.) |
|---|---|---|
| Small incendiary ($\Omega \cong 0.5$) ... ... ... | 10,000 | 400 |
| | 20,000 | 400 |
| Heavy incendiary or small explosive ($\Omega \cong 2$) ... | 10,000 | 600 |
| | 20,000 | 700 |
| Medium case bomb (500-1,000lb.) ($\Omega \cong 5$) ... | 10,000 | 750 |
| | 20,000 | 900 |
| Large heavy case bomb ($\Omega \cong 15$) ... ... | 10,000 | 900 |
| | 20,000 | 1,150 |
| | 40,000 | 1,500 |

Using the above data, the depth of penetration for unit sectional density is approximately as follows:—

| Material. | Impact velocity. | Penetration in feet for unit sectional density. |
|---|---|---|
| Concrete (strength 2,800 lb./sq. in.) | 400 | 0.2 |
| | 800 | 0.6 |
| | 1,200 | 0.9 |
| Timber ... ... ... ... | 400 | 1 |
| | 800 | 2.6 |
| | 1,200 | 4.2 |
| Loose earth ... ... ... ... | 400 | 2 |
| | 800 | 4.8 |
| | 1,200 | 5.5 |

Thus a small incendiary bomb (sectional density $\Omega = 0.5$) will penetrate 1 foot of earth or 0.1 foot of concrete if dropped from 20,000 feet.

A 500lb. bomb ($\Omega = 5$) dropped from the same height will penetrate 3 feet of concrete or 25 feet of earth.

A 2,000lb. bomb ($\Omega = 15$) might penetrate 75 feet of earth.

At very high speeds of impact, the resistance of sand or earth is greatly increased. The relative depth of penetration for bomb fragments ($v = 5{,}000$ feet/sec.) for earth and concrete is thus not 10/1 (as in the above table) but only of the order of 2-3/1.

*The Effectiveness of Aerial Bombardment in Spain.* (Les Ailes, No. 927, 23/3/39, p. 11.) (66/2 France.)

The author has discussed the effectiveness of aerial bombardment with various officers and men of the Republican forces which recently retreated into France.

The following are the principal conclusions:—

1. Complete demoralisation of the civilian population when exposed to high explosives. The heavy (500 kg.) bomb will cause the collapse of any building (blast) and rescue work will be rendered very difficult by the subsequent use of splinter bombs.
2. Complete demoralisation of troops in trenches subjected to heavy and continuous aerial bombardment. Even if the actual loss of life is relatively small, the troops are incapable of offering any resistance and the trench is taken without a shot being fired.
3. Troops in the open, especially mechanised columns on roads, are extremely vulnerable to machine gun attack from the air and to the effect of small splinter bombs.
4. The ordinary soldier as normally equipped is incapable of any effective reply to aerial attack.

*Civil Defence (Methods of Adequate Protection Against Aerial Attack).* (C. W. Glover, published by Chapman and Hall. Reviewed in Nature, No. 3,622, 1/4/39, pp. 537-8.) (66/3 Great Britain.)

The first part of the book deals with war gases and methods of protection. The second part considers the problem of buildings, trenches and shelters. Provided the walls of steel framed buildings are sufficiently thick (12in. ferro-concrete or 14in. of brick) the ground floor (if there is no basement) is recommended as the best level for a shelter, provided the floors above are capable of holding up any debris that may fall on them.

As regards trenches, the zig-zag type has been found in Spain to be preferable to the crenellated. If a roof is provided it should only be sufficiently strong to hold up splinters, since a roof proof against a direct hit is in most cases impracticable.

From a practical point of view small dispersed shelters are easier to construct and, generally speaking, not more than 50 people should be accommodated in one place.

The book ends with a description of the Home Office A.R.P. Organisation.

*The Resistance of Concrete to High Explosives.* (Engineering, Vol. 147, No. 3,820, 31/3/39, p. 386.) (66/4 Great Britain.)

The resistance of concrete to high explosives can be increased by the addition of granite dust to the aggregate. The mix recommended has the following composition:—

$2\frac{1}{4}$ parts $\frac{3}{16}$in. granite and sand.
$3\frac{3}{4}$ parts $\frac{3}{4}$in. to $\frac{1}{4}$in. granite.
1 part cement.

The water/cement ratio in the above is 0.53. Slabs made of this material, 2ft. by 2ft. by 6in. were subjected, after ageing, to the action of $\frac{1}{2}$oz. charge of

Abelite placed in a central plugged hole of the slab, 1⅛in. diameter and 3¼in. deep. Similar tests were carried out on slabs of normal concrete.

The published photographs show the superiority of the granite mix, the greater cohesion of the latter being accounted for by the keying action of the sharp granite particles.

*A Complete Plant for A.R.P. Emergency Power Generation.* (Mechanical World and Engineering Record, 24/3/39, pp. 296-7. Metropolitan Vickers Technical News Bulletin, No. 654, 31/3/39, p. 3.) (66/5 Great Britain.)

The plant described has been installed at Portsmouth as a protection against interruption of production by the failure of the public electricity supply. The apparatus, housed under reinforced concrete, is driven by a 250 b.h.p. Petter "Superscavenge" Diesel engine. This is coupled to a single-bearing alternator with overhung exciter made by the English Electric Co. The unit runs at 500 r.p.m. and the generator is designed to have high efficiency at fractional loads. Voltage regulation is maintained by B.T.H. carbon-pile automatic regulator, and paper insulated armoured cable in an underground duct is employed throughout. The air compressor, exhaust cooling and emergency lighting systems are described.

Illustrated with two photographs.

*The Training of Pilots in the National Socialist Flying Corps* (*N.S.F.K.*) (O. R. Thomson, published by C. J. E. Volckmann, Berlin.) (66/6 Germany.)

The object of the N.S.F K. is threefold:—

1. Create air-mindedness in the German people.
2. To provide pre-military training.
3. To coordinate sporting aviation in Germany.

The membership is voluntary, but limited to the following classes:—

1. Retired Air Force members who have had flying experience.
2. Civilians who have been trained as pilots or observers, balloon and glider pilots.
3. All members of the Air Section of the Hitler Youth organisation older than 18 years.
4. All members of the flying and gliding sections of the former D.L.V.

The N.S.F.K. is organised into 17 groups with headquarters distributed over the whole of Germany. These groups are further subdivided into smaller units so that practically every village can easily get into touch with the organisation.

The booklet under review deals mainly with the training for the A2 pilot's licence, which is usually obtained in 6-8 weeks (15-22 hours in the air). The description of the various control movements during take-off, landing and curvilinear flight are simply explained with the help of diagrams. The book certainly fulfils its object since most young readers will be tempted to try their own hand!

*Circulation Measurements About the Tip of an Aerofoil During Flight Through a Gust.* (A. M. Kuethe, N.A.C.A. Tech. Note No. 685, Feb., 1939.) (66/7 U.S.A.)

Measurements were made of the circulation about the rectangular tip of a short-span aerofoil passing through an artificial gust of known velocity gradient. A Clark Y aerofoil of 30-centimetre chord was mounted on a whirling arm and moved at a velocity of 29 metres per second over a vertical gust with a velocity of nearly seven metres per second. Flow angles were measured with a hot-wire apparatus.

CONCLUSIONS.

1. During the first stages of the motion of a wing into a gust, the measurements indicate that the trailing vortices behind a wing of rectangular plan form are concentrated nearer to the wing tips than they are during flight.

2. For conventional plan forms, *i.e.*, with the chord constant or decreasing towards the tips, wing-tip loads in gusts do not exceed those experienced in steady flight at angles of attack equal to the maximum value reached in the gusts.

3. The rate at which the lift at the tips of a wing entering a gust is realised is in satisfactory agreement with that predicted on the basis of the two-dimensional theory of von Karman and Sears.

*Large Wind Power Generators.* (C. Martini, Elektrotechnik und Maschinenbau, 17/2/39, pp. 83-9. Metropolitan Vickers Tech. News Bulletin No. 652, 17/3/39, p. 9.) (66/8 Germany.)

The author makes a weight comparison of wind power generators according to the Honnef system, the weights being plotted as a function of the three variables: number of poles, air induction and diameter. Illustrated with six diagrams.

*Tests of N.A.C.A. 0009, 0012 and 0018 Aerofoils in the Full-Scale Tunnel.* (H. J. Goett, W. K. Bullivant, N.A.C.A. Tech. Report No. 647, 1938.) (66/9 U.S.A.)

An investigation was conducted in the N.A.C.A. full-scale wind tunnel to determine the aerodynamic characteristics of the N.A.C.A. 0009, 0012, and 0018 aerofoils, with the ultimate purpose of providing data to be used as a basis for comparison with other wind-tunnel data, mainly in the study of scale and turbulence effects. Three symmetrical 6- by 36-foot rectangular aerofoils were used. The Reynolds number range for minimum drag was from 1,800,000 to 7,000,000 and for maximum lift, from 1,700,000 to 4,500,000. The effect of rounded tips was determined for each of the aerofoils. Tests were also made of the N.A.C.A. 0012 aerofoil equipped with a 0.20*c* full-span split flap hinged at 0.80*c*. Tuft surveys were included to show the progressive breakdown of flow near maximum lift.

Momentum surveys were made in conjunction with force measurements at zero lift as an aid in converting force-test data to section coefficients.

*Turbulence in the Boundary Layer.* (H. L. Dryden, J. Aeron. Sci., Vol. 6, No. 3, January, 1939, pp. 85-105.) (66/10 U.S.A.)

It is well known that certain wind tunnel measurements are affected by the degree of turbulence of the wind stream. Thus the drag of a sphere may vary by a factor of 4, that of an airship by a factor of 2 and the maximum lift of an aerofoil by a factor of 1.3, depending on the turbulence of the air stream.

After discussing how both the intensity and the scale of the turbulence can be measured by means of special hot wire anemometers, the author considers the effect of turbulence of the air stream on an originally laminar boundary layer.

It is known that such a layer will become turbulent at a certain distance from the stagnation point of the flow, the position of this point of transition depending amongst other factors on the intensity and scale of the turbulence of the incident flow. Other possible factors include the Reynolds number, the pressure gradient, and curvature and roughness of the surface. The position of the separation point where the laminar boundary layer leaves the surface may also have an effect.

These various factors are being examined with a view to predicting the transition point on a given surface theoretically. Much more work will, however, be required before a satisfactory answer can be given in all cases.

*The Correlation of Boundary Layer Transition Data.* (J. Bricknell, J. Aeron. Sci., Vol. 6, No. 5, March, 1939, pp. 203-205.) (66/11 U.S.A.)

It is now generally admitted that the conditions leading to transition cannot be stated in terms of parameters based on local mean values.

The author attempts to provide a more satisfactory correlation based on the previous history of the laminer boundary layer and for this purpose introduces the concept of the equivalent flat plate, first suggested by von Doenhoff.

Applied to flight transition data on three aerofoil sections, the correlation is fairly satisfactory.

Since the mechanism of transition in turbulence-free air (*i.e.*, flight) is probably different from that existing in turbulent streams, the method in its present form must be considered as only of limited application.

*Metal Aircraft Construction.* (C. W. Vogelsang, Published by R. C. Schmidt, Berlin, 1938.) (66/12 Germany.)

After a brief survey of available materials, the author considers the following aspect of the problem in greater detail:—

(1) Deep Drawing and Pressed Profiles.
(2) Riveting and Riveting Machines.
(3) Welding of Light Alloys.
(4) Fuselage Construction.
(5) Undercart and Floats.
(6) Wing Construction.
(7) Corrosion Protection.

There are also some notes on inspection and series production. Most of the examples illustrated refer to German Practice (Junkers, Dornier, Focke-Wulf).

The book is mainly intended for engineering students as an introduction to more advanced study, and the author has succeeded in condensing a fair amount of practical information into the relatively small space of 160 pages. The absence of an index is a drawback.

*The Aerodynamic Characteristics of Full-Scale Propellers having 2, 3 and 4 Blades of Clark Y and R.A.F. 6 Aerofoil Sections.* (E. P. Hartmann and D. Biermann, N.A.C.A. Tech. Report No. 640, 1938.) (66/13 U.S.A.)

Aerodynamic tests were made of seven full-scale 10-foot-diameter propellers of recent design comprising three groups. The first group was composed of three propellers having Clark Y aerofoil sections and the second group was composed of three propellers having R.A.F. six aerofoil sections, the propellers of each group having two, three, and four blades. The third group was composed of two propellers, the two-blade propeller taken from the second group and another propeller having the same aerofoil section and number of blades but with the width and thickness 50 per cent. greater. The tests of these propellers reveal the effect of changes in solidity resulting either from increasing the number of blades or from increasing the blade width.

It was found that (1) increasing the solidity by adding blades had a lesser adverse effect than increasing it by increasing the blade width; (2) the loss in efficiency commonly conceived to be the result of increasing the number of blades was not fully realised, only about 2 per cent. difference in peak efficiency between a two-blade and a four-blade propeller being measured; and (3) an increase in solidity tended to delay the stall and to increase the efficiency in the take-off range.

Propeller design charts and methods of computing propeller thrust are included.

*Tandem Air Propellers.* (E. P. Lesley, N.A.C.A. Tech. Note No. 689, February, 1939.) (66/14 U.S.A.)

Tests of two-blade, adjustable-pitch, counter-rotating tandem model propellers, adjusted to absorb equal power at maximum efficiency, were made at Stanford University.

The characteristics, for 15°, 25°, 35°, and 45° pitch settings at 0.75 R of the forward propeller and for 8½ per cent., 15 per cent., and 30 per cent. diameter

spacings, were compared with those of two-blade and four-blade propellers of the same blade form.

The tests showed that the efficiency of the tandem propellers was from 0.5 per cent. to 4 per cent. greater than that of a four-blade propeller and, at the high blade-angle settings, not appreciably inferior to that of a two-blade propeller.

It was found that the rear tandem propeller should be set at a blade angle slightly less than that of the forward propeller to realise the condition of equal power at maximum efficiency. Under this condition the total power absorbed by the tandem propellers was from 3 per cent. to 9 per cent. more than that absorbed by the four-blade propeller and about twice that absorbed by a two-blade propeller.

*The Determination of the Product of Inertia of Aircraft Control Surfaces.* (A.C.I.C., No. 711, 15/9/38.) (66/15 U.S.A.)

The product of inertia is defined and its physical significance discussed.

Three methods for determining the product of inertia experimentally are discussed. These are as follows: first, by calculations based on the experimental determinations of the moments of inertia about three axes lying in the same plane, two of which are mutually perpendicular; second, by measuring the torque produced by a definite angular acceleration; and third, by the use of auxiliary balance weights to reduce the product of inertia to zero. In connection with the first method, an original scheme for locating the third axis so as to reduce the effect of unavoidable experimental errors is developed theoretically, which, when applied to an actual case, reduced the maximum possible error in the final result from 105 per cent. to less than 7 per cent.

*Tests on Experimental Flotation Compartment Test Specimens.* (A.C.I.C., No. 712, 15/9/38.) (66/16 U.S.A.)

Flotation compartments can be made watertight and airtight if the type of structure is adaptable to being sealed with tape impregnated with sealing compound. The technique of assembly and experience of mechanics in fabricating this type of structure contributes materially in making tight joints.

A reasonable test pressure is one-half pound per square inch.

A sealing compound should be one with which cotton tape can be impregnated and which will not become hard and flake off due to age.

The rivet spacing should be close enough to prevent flexing or working of the sheets in the seam.

A packing gland type of fitting is satisfactory for use on vent tubes and conduits which pass through the flotation compartments.

*Operating Safety and Requirements of the Modern Transport.* (W. B. Oswald, J. Aeron. Sci., Vol. 6, No. 4, Feb., 1939, pp. 127-36.) (66/17 U.S.A.)

Four principal emergencies occurring during operation of transport aeroplanes are investigated: (1) power plant failure during take-off; (2) power plant failure during normal flight; (3) misjudged landing with climb-out from the field, and (4) adverse operating conditions at low efficiency, such as with an irregular load of ice. Landing speed and control at low speed are also studied.

Four engines are desirable for safe all-year operation of long and medium-range aeroplanes because of the large reserve of power after propulsive unit failure. The two-engine aeroplane seems suitable for short-range operation where, with small fuel load, a good payload can be maintained without exceeding safe loading.

The tricycle landing gear has exceptional stability on the ground, hence contributes both to fool-proof take-off and landing, particularly under adverse conditions. Greater load can be landed in shorter distance with the tricycle gear, hence it adds safety and efficiency to an aeroplane.

*Calculation of the Induced Efficiency of Heavily Loaded Propellers having Infinite Number of Blades.* (F. Lösch, L.F.F., Vol. 15, No. 7, 6/7/38, pp. 321-5. Available as Translation T.M. 884.) (66/18 Germany.)

Based on a suggestion made by L. Prandtl, the present report contains an approximate method of computing the induced efficiency of heavily loaded propellers in suitable form for extension to finite number of blades, and a comparison of the results obtained by this simple method with the data of the Betz-Helmbold theory for heavily loaded propellers. It is found that—quite apart from the accord in the limiting case of light loading—good agreement obtains for relatively low as for relatively high coefficients of advance. A direct calculation of the ($c_s$, $\eta_i$) curves by the two methods affords excellent agreement up to $\eta_i = 0.5$, even for coefficients of advance in the neighbourhood of 0.5, 1, 2.

*The Induced Efficiency of Optimum Propellers having a Finite Number of Blades.* (K. N. Kramer, L.F.F., Vol. 15, No. 7, 6/7/38, pp. 326-333. Available as translation T.M. No. 884.) (66/19 Germany.)

The highest possible induced efficiency $\eta_i$ for free-running propellers can be computed on the assumption of optimum circulation distribution and vanishing profile drag. This induced efficiency is thus a measure of the quality of constructed propellers and plays a similar role to the induced drag of a wing with elliptic lift distribution when considering the energy balance of an aeroplane.

The author determines the functional relationships between propeller load coefficient $\lambda_s$ and $\lambda_1$ and $\eta_i$ (partly by exact calculation and in part by interpolation) for 2, 3, 4, 6, and 8-bladed propellers for any value of the coefficient of advance $\lambda$.

The results are incorporated in a series of graphs from which $\eta_i$ can be read off in $\lambda$, $x_s$ and the number of blades $\zeta$ are given.

The following is an example:—

$x_s = .09$; $\lambda = .45$.

| $\zeta$ | $\eta_i$ |
|---|---|
| 2 | .93 |
| 3 | .945 |
| 6 | .955 |
| 8 | .960 |
| $\infty$ | .965 |

The axial efficiency $\eta_a$ under the given conditions $= .978$.

The difference between $\eta_a$ and $\eta_i$ is a measure of the losses due to rotation of slipstream and finite blade number.

*American Verdict on Large Four-Engined Civil Aircraft.* (G. E. Marque, Inter. Avia., No. 630, 28/3/39, p. 1-3.) (66/20 U.S.A.)

The principal characteristics of the aircraft types reviewed are given in the following table:—

| Type. | D.C.-3. | C.W.-20. | B. 307-S. | D.C. 4. |
|---|---|---|---|---|
| Weight (empty) ... ... | 16,300 | 24,000 | 31,000 | 46,000 lb. |
| Cost (complete) ... ... | 117,500 | 225,000 | 337,000 | 450,000 $. |
| Useful load ... ... ... | 8,100 | 12,000 | 14,000 | 19,000 lb. |
| Total cost per lb. of useful load ... ... ... ... | 14.50 | 18.75 | 24.07 | 23.67 $. |
| Engine ... ... ... | 2 Wright | 2 Wright | 4 Wright | 4 P. & W. |
| Take-off power per engine ... | 1,100 | 1,600 | 1,100 | 1,400 h.p. |
| Cruising speed ... ... | 182 | 205 | 215 | 210 m.p.h. |
| Maximum range (65 per cent. power, no wind) ... ... | 1,650 | 1,700 | 1,520 | 1,870 m. |
| Payload at maximum range | 2,325 | 5,000 | 5,070 | 5,110 lb. |
| Load factor to cover direct flying costs for round trip Chicago-New York (1,450 miles) ... ... ... | 37% | 32% | 41% | 37% |

From the above the author concludes that a twin-engined aircraft of the type Curtiss Wright C.W.20 is the most economical solution.

*Junkers Fully Automatic V.P. Airscrew.* (Inter. Avia., No. 631, 31/3/39, p. 6.) (66/21 Germany.)

A hydraulic motor is fixed to the front of the hub; according to the direction of the oil flow, it acts through a gear either in one or the other direction on the driving worm, which engages with the worm wheel on the blade root and rotates the blade. The direction of the oil flow is controlled by a piston which is moved from one side by a centrifugal governor and from the other side by a spring. By adjusting the tension of the spring, the engine speed can be set within a wide range. The airscrew provides also for full feathering position which is effected by cutting out the governor and allowing the hydraulic motor to run in the direction of coarse pitch until the blades reach the limit stop.

*The Centenary of the Birth of Count Zeppelin.* (E. Breithaupt, Luftwissen, Vol. 5, No. 7, July, 1938, pp. 235-238.) (66/22 Germany.)

The following table gives the structural weights in gm. per cubic metre of gas for a number of zeppelin airships:—

| Structural Elements. | Type, Date, Capacity. LZ. 62 (1916). (56,000 M³). | L.59 (1917). (68,000 M³). | LZ. 127 (1930). (112,000 M³). | LZ. 129 (1935). (200,000 M³). |
|---|---|---|---|---|
| Frame including cover and ballonets (installed) ... ... | 423.1 | 293.9 | 363.1 | 392.3 |
| Engine ... ... ... ... | 142.9 | 79.3 | 101.1 | 79.8 |
| Tanks ... ... ... ... | 21.7 | 18.0 | 30.8 | 16.0 |
| Equipment including accommodation for crew ... ... ... | 43.2 | 16.7 | 45.3 | 46.3 |
| Special fittings for passengers or load carrying ... ... ... | 6.4 | — | 25.0 | 56.5 |

It will be noted that in spite of a fourfold increase in size (gas capacity) since 1916, the unit weight of the frame and gas fittings has decreased slightly. The main improvement has been in the weight and specific consumption of the power plant.

Reference is made to the new silk fabric for the ballonets (the use of this material increased the lift of LZ.130 by 4 tons) and water recovery. In the case of normal Diesel fuels, the exhaust contains sulphuric acid (corrosion!). This difficulty was overcome by utilising Kogasin fuel, a by-product Fischer-Tropsch synthetic fuel process.

*The Landing Impact of Aircraft Floats.* (C. Schmieden, Ing. Arch., Vol. 10, No. 1, Feb., 1939, pp. 1-13.) (66/23 Germany.)

Previous investigation on landing impact of floats assumed two dimensional flow, *i.e.*, the float is infinitely long. The author investigates the effect of having a finite float length and in order to reduce the mathematical difficulties a float shape is assumed such that the pressure surface is in the form of an ellipse, which remains of constant shape (but increasing size) during the impact process.

The results are given in the form of non-dimensional co-efficients, the two-dimensional impact case being also given for comparison.

It appears that the maximum value of the impact force occurs appreciably earlier in the case of the finite float.

*The Controlled Curvilinear Horizontal Flight of an Aircraft.* (E. Mettler, Ing. Arch., Vol. 9, No. 5, Oct., 1938, pp. 327-343.) (66/24 Germany.)

The author assumes a path for the C.G. of the aircraft and calculates the necessary control motions from the six fundamental equations of motion. The investigation is limited to normal attitudes of flight (in stalled and moderately fast rates of turn), the flight path being horizontal throughout.

Two flight paths are studied in detail. The first corresponds to a relatively sharp turn through 40°, both initial and final path being straight. During this manœuvre the change in speed is negligible. The second path corresponds to the change from straight line motion to steady circular flight, during which there occurs an appreciable drop in speed. The results of the investigation are given in the form of graphs which give the motions of the aileron, elevator and rudder respectively plotted on a basis of length of flight path.

As would be expected, the ailerons and rudder are reversed in the flight path position corresponding to the centre of the turn (case I), whilst the elevator reaches its maximum deflection at approximately the same position. All controls are at zero at the beginning and end of the turn. In case II (continuous turn), aileron and rudder, after an initial deflection, both soon return to approximately zero the curve being flown at a constant elevator deflection. These results naturally depend on the type of flight path and aircraft assumed.

*The Effect of Propeller Slipstream on the Aerodynamic Characteristics of a Wing.* (J. Kampe de Ferret and A. Fauguet, G.R.A. Tech. Note No. 2, Les Ailes, No. 929, 6/4/39, p. 7.) (66/25 France.)

The report deals with wind tunnel tests on a model of 1.25 m. span and .25 m. chord. The two-bladed propeller had a diameter of 200 mm. and was driven by a high-speed electric motor mounted inside the fuselage. The experiments were carried out in the large wind tunnel at Lille at a constant air speed of 25 m./sec. and showed that the no-lift incidence was unaffected by the operation of the propeller. The maximum lift coefficient, however, increased from 1.2 to 1.32

The propeller retards the break away of the flow over the central wing section and also has a profound influence on the downwash.

Due to the spiral motion of the air this angle of downwash differs on the two sides of the vertical tail plane and thus calls for a corresponding difference in trim of the horizontal control surfaces.

It is interesting to note that the drag of the stationary propeller is least with the axis of the propeller parallel to the leading edge of the wing.

*The Charging Process in a High Speed Single Cylinder Four-Stroke Engine.* (B. Reynolds, H. Schecter and E. S. Taylor, N.A.C.A. Tech. Note No. 675, Feb., 1939.) (66/26 U.S.A.)

The experiments were carried out on a Wasp, jr. aircraft engine cylinder, $5\frac{7}{16}$in. bore and $5\frac{1}{2}$in. stroke, compression ratio 6.5, the speed of operation ranging from 1,500 to 2,600 r.p.m. No inlet or exhaust pipes were fitted, the fuel being injected directly into the inlet port by means of a Bosch high-speed injector pump. The air consumption was estimated from the indicated m.e.p. (brake and motoring), a relationship having been obtained previously for this engine when fitted with an inlet pipe and Roots displacement meter. Indicator diagrams were taken with the M.I.T. balance pressure indicator, which had been modified to increase its accuracy.

The following conclusions were drawn:—

1. Pressure drop in the valve is responsible for an extremely small part of the volumetric deficiency on the cylinder tested, even at 2,380ft. per minute mean piston speed.
2. The rise in temperature of the charge coming through the inlet valve and in the cylinder before inlet closing is responsible for a relatively large volumetric deficiency.
3. It is possible to calculate the pressure drop in the valve with good accuracy.
4. The friction of the air in the valve port is responsible for most of the pressure drop.

It is recommended that further study on this problem be directed particularly toward a study of the heat transfer process.

*Comparative Performance of Engines Using a Carburettor, Manifold Injection and Cylinder Injection.* (O. W. Schey and J. D. Clark, N.A.C.A. Tech. Note No. 688, Feb., 1939.) (66/27 U.S.A.)

The comparative performance was determined of engines using three methods of mixing the fuel and the air: the use of a carburettor, manifold injection, and cylinder injection. The tests were made of a single-cylinder engine with a Wright 1820-G air-cooled cylinder.

Each method of mixing the fuel and the air was investigated over a range of fuel-air ratios from 0.10 to the limit of stable operation and at engine speeds of 1,300 and 1,900 r.p.m. The comparative performance with a fuel-air ratio of 0.08 was investigated for speeds from 1,300 to 1,900 r.p.m.

The results show that the power obtained with each method closely followed the volumetric efficiency; the power was, therefore, the highest with cylinder injection because this method had less manifold restriction. The difference amounted to 7 per cent. at 1,900 r.p.m. The values of minimum specific fuel consumption obtained with each method of mixing of fuel and air were the same. For the same engine and cooling conditions, the cylinder temperatures are the same regardless of the method used for mixing the fuel and the air.

Additional advantages of cylinder injection are:—

1. Possibility of using safety fuel.
2. Possibility of scavenging.
3. Perfect distribution on in-line engines.

*Non-Magnetic Oil Engines.* (Engineer, Vol. 167, No. 4343, 7/4/39, p. 434.) (66/28 Great Britain.)

The propelling engines on the Admiralty magnetic survey vessel "Research" weigh 370 cwt. and do not contain more than 250lb. of magnetic material. The crankshaft and layshafts are made of manganese-nickel-chrome steel, which is practically non-magnetic. The forgings for these shafts cost about 20 times as much as standard high tensile steel!

The bed plate is a bronze alloy and the flywheel of solid bronze.

The cylinder head and crankcase are of aluminium bronze, centrifugally cast Ni-resist iron (non-magnetic is used for the cylinder liners, the aluminium cylinder being cast around them).

The engine is of the single acting two-stroke type and develops 160 b.h.p. at 375 r.p.m.

*Aircraft Engine Power Estimation from Intake Manifold Density.* (T. W. Rhines and P. W. Schipper, J. Aeron. Sci., Vol. 6, No. 3, January, 1939, pp. 106-13.) (66/29 U.S.A.)

A method of estimating engine power output in flight by means of calibrations based on the density of the fuel-air mixture in the intake pipe is described. Comparison of this method with the conventional manifold-pressure calibration is made, and test data taken with a torque indicator in flight are used to indicate the relative accuracies of the two methods. The comparison shows that there is little to choose between the two methods at the present stage of development of the newer one. However, improvement of the density method through advances in test technique is probable, because its basis is fundamentally sound. The manifold-pressure method is not on such a firm basis, so further advances with it are unlikely.

*A Wear and Lubricant Testing Machine, Developed by the Timken Roller Bearing Company.* (Metal Industry, 24/3/39, pp. 347-8. Metropolitan Vickers Technical News Bulletin, No. 654, 31/3/39, p. 6.) (66/30 Great Britain.)

Details are given of the construction, operation and testing procedure of a machine developed for testing lubricants and bearing metals. It consists of a lever system mounted on universal knife edges, by which a load can be accurately

transmitted to a metal test piece revolving in a ground metal cup. The test piece is drawn through a reduction gear by an electric motor and rotates at any chosen speed. Lubricant is maintained at a given temperature and flows at a calibrated rate over the test pieces. For lubricant testing, the condition of the surfaces after the test is noted. For material testing, the lost metal is measured by weight. Modifications allow the testing of the lubricating qualities of greases to be undertaken. Illustrated with one photograph.

*Compressed or Liquefied Gas Fuel for Small River Craft.* (Soudostroienie, No. 4, 1938. Eng. Absts., Vol. 2, No. 1, Section 3, Feb., 1939, pp. 9-10.) (66/31 U.S.S.R.)

The condensable gases (propane, butane and their compounds) are obtained by reworking naphtha and coal and are also found in the form of naphtha gas in various oil fields. They are usually stored at a relatively low pressure (15-20 atmospheres).

The compressible gases (natural, illuminating, and producer gas) require much higher pressures (of the order of 200 atmospheres).

The great advantage of gas fuel is that it requires no modification to a carburettor engine so that liquid fuels can be used when available.

The National Research Department of the U.S.S.R. claim the following benefits for gas fuels:—

(1) The engine is started more easily, especially at low temperature.
(2) Greater flexibility.
(3) Cleaner engine and no oil dilution.

In addition to supply stations on shore, a number of floating stations have been provided from which the boats may refuel.

*The Ignition Lag in the Diesel Engine.* (K. Neumann, Forschung, Vol. 10, No. 1, Jan.-Feb., 1939, pp. 2-14.) (66/32 Germany.)

The mixture formation in the combustion chamber of a Diesel engine depends on the atomisation and vapourisation of the injected fuel.

The author investigates mathematically the variation in size and number of drops during the period of the ignition lag, both in the absence and in the presence of vapourisation. A quantitative estimate of the proportion of fuel mist and fuel vapour is carried out and it is concluded that the lag period is mainly governed by the time necessary to vapourise a certain proportion of the fuel.

*Ignition Lag and Propagation of Combustion in the Direct Injection Diesel Engine.* (L. Herele, Forschung, Vol. 10, No. 1, Jan.-Feb., 1939, pp. 15-27.) (66/33 Germany.)

The experiments were carried out on a three-cylinder two-stroke Krupp Diesel, developing 75 h.p. at 500 r.p.m. The engine was operated under full load conditions, both the ignition lag and the propagation of combustion being measured by the ionisation method, using 36 special point electrodes placed inside the combustion space of one cylinder. It appears that ignition starts almost simultaneously at various isolated regions in the confines of the fuel jet, which do not occupy a fixed position for successive explosions. The combustion is not propagated along the jet but spreads out laterally, conforming to local turbulence variations.

The irregularities in the spread of the combustion revealed by the ionisation method are confirmed by observations of the radiation emitted through a window in the combustion chamber.

On the other hand the indicator diagrams show that the beginning of the rapid pressure rise associated with the combustion occurs at the same part of the stroke with great regularity.

*Measurement of the Thickness of Metal Plates from One Side.* (A. G. Warren, J. Inst. Elec. Eng., Vol. 84, No. 505, January, 1939, pp. 91-5.) (66/34 Great Britain.)

The method described here is a conductivity method which does not depend upon any previous knowledge of the specific conductivity of the material. Although the actual measurements made depend upon the conductivity, this quantity is automatically eliminated during computation and the essential relationships used are purely geometrical and do not depend upon the physical properties of the material (imagined homogeneous.)

When corrosion is general the problem is simply that of determining the thickness of the plate at a number of places after it has been in use for some time. The apparatus employed may also be used in a search for local corrosion pits, which are not uncommon in some structures.

The theory of the method when applied to an extensive plate is given. Only a brief indication of the theory underlying the application to plates of limited area is here published, but curves are given enabling the method to be applied in practice.

*Static Pressure Recorder.* (J. Kampé de Feriét and G. Rollin, G.R.A. Note Technique, No. 1, January, 1939.) (66/35 France.)

Two sets of pressure orifices are placed on a hollow sphere, 60 mm. diameter, in such a way that the indication of either set alone is independent of the direction of the relative wind over a large range of incidence.

The orifices are connected together through calibrated passages inside the sphere, the true static pressure being tapped off at an intermediate point.

In the particular instrument, one orifice is placed at the end of a tube fixed centrally and longitudinally in the throat of Venturi, piercing the sphere along a diameter. The second set of orifices is placed over the rear surface of the sphere and is connected to a common pressure chamber which communicates with the total pressure pipe.

From the calibration curves it appears that the static pressure as read from a suitable intermediate point is practically independent of wind direction over the range $\pm 25^{\circ}$.

*Abstractors Note*:—The principle of this instrument appears to be very similar to the method advocated by Kiel (L.F.F. Vol. 15, No. 12, 10/12/38, pp. 583-597, Air Ministry Abstract 63/12).

*Relation of Camera Error to Photogrammetric Mapping.* (I. C. Gardner, Bur. Stan. J. Res., Vol. 22, No. 2, February, 1939, pp. 209-38.) (66/36 U.S.A.)

A portion of the errors in a map constructed from aeroplane photographs arises from differences between the actual performance of the aeroplane camera and the postulated performance as defined by the calibration constants. The different sources of errors of this nature are enumerated and equations are derived showing the relation between errors in the calibration constants of the camera and the resulting errors in the map.

Equations are given for errors in the map arising from incorrect value of the calibrated focal length, distortion, and incorrect location of the principal point. Other sources of error in the camera, such as failure of the film to lie in a plane, the character of performance of the shutter, and imperfect filters are considered and their effects upon the image evaluated.

*Constant Speed Control Theory.* (H. K. Weiss, J. Aeron. Sci., Vol. 6, No. 4, Feb., 1939, pp. 147-52.) (66/37 U.S.A.)

The general theory of the constant speed control is reviewed for an " error " and " rate-of-change of error " control applied to a system possessing inertia but no damping or inherent speed stability. It is shown that the most satisfactory

control is one which has a high natural frequency, small inertia, and little or no Coulomb friction. Viscous damping is shown to have a less detrimental effect on the response of the control than control inertia, and the general conclusion is drawn that stability of the motion is secured by viscous damping in the control, while good performance is obtained by keeping the inertia of the control small.

*Torque Meter for Aircraft Models Fitted with Propellers.* (R. Silber and Ad. Oudart, Pub. Sci. et Tech. B.S.T., No. 84, 1939.) (66/38 France.)

The casing of the electric motor driving the propeller is mounted on ball bearings and the torque reaction is measured by the twist of a spiral spring. The fuselage of the model is fitted with a small illuminated window, the twist being read by means of a telescope placed outside the air current.

The model has a span of the order of 1 m., the electric motor having a diameter of 5 cm. and a length of 17 cm. The power output is of the order of 150 watts, the speed range being 5,000-15,000 r.p.m.

The torque meter measures torques between .01 + .04 kgm. with an accuracy of the order of .5 per cent. at .02 kgm.

*On the Effect of the Density of the Air upon the Pitot Static Tube Coefficient.* (T. Sasaki and K. Hattori, Aeron. Research Inst., Tokyo, Report No. 173, February, 1939.) (66/39 Japan.)

The calibration was carried out in the low temperature and low pressure wind tunnel at speeds ranging from 27 m./sec. to 71 m./sec. at various air densities from 1.285 kg./m.$^3$ to .392 kg./m.$^3$.

The reference standard was a windmill previously calibrated on a rail track vehicle (operating in a long closed tunnel) and on a whirling arm placed inside the low density tunnel. It appears that the constant $K = ap/\rho v^2$ of the pitot decreases roughly 4 per cent. as the air density is decreased over the range stated above.

*Flight Altitude Control.* (C. H. Colvin, J. Aeron. Sci., Vol. 6, No. 5, March, 1939, pp. 206-210.) (66/40 U.S.A.)

Maintenance of clearance between individual aeroplanes and the ground respectively can be ensured by the following rules:—

(1) While on a given route section, all pilots must keep the barometric scales of their altimeters set to the same Kollsman number (altimeter sea level pressure) as transmitted by the station controlling that route section.

(2) Except in emergencies, pilots must fly at the odd or even thousand foot altitudes presented by the C.A.R., as indicated by their altimeters. A permissible minimum altitude is prescribed for each flight level. At lower temperatures the pilot must go to the next higher level.

(3) In emergencies the pilot must not fly at a lower indicated altitude than is provided by " dead line " altitude/temperature chart for the route section utilised.

The advantages of this system of altitude control are:—

(1) The same instruments and methods are used for maintaining vertical separation of aeroplanes as for maintaining ground clearance.

(2) No instrument equipment is required in addition to that now regularly carried.

(3) The barometric scale of the altimeter is always set to the correct values for landing at the control airport.

*The General Theory of Relaxation Applied to Linear Systems.* (G. Temple, Proc. Roy. Soc., Series A, Vol. 169, No. 939, 7/3/39, pp. 476-500.) (66/41 Great Britain.)

The author gives a general account of the application of relaxation methods to the solution of linear equations. Southwell's original method for linear algebraic

equations in a finite number of unknown variables has been the inspiration of the whole investigation. By replacing his method of successive relaxation by a method of steepest descents it has been possible to attack linear operational equations, linear integral equations, and linear differential equations. In each case the new methods give successive approximations which converge to the accurate solution of the problem. Two outstanding problems must be left for future investigation—the numerical solution of particular problems of physics and engineering, and the extension of the methods to non-linear equations.

*Light Ray Control for Machine Tools.* (Machinery, 9/3/39, pp. 713-7. Metropolitan Vickers Technical News Bulletin No. 652, 17/3/39, p. 3.) (66/42 Great Britain.)

The employment is described of a photo-electric circuit to control the sequence of operations in the drilling and reaming of oil reservoir holes in main bearing journals of A.E.C. engine crankshafts. The machine, which is in effect two two-spindle vertical machines mounted side by side on a common base, was designed specifically for this operation, and both it and the control gear are fully described. Illustrated with four photographs and four diagrams.

*Some Recent Developments in Resistance Welding Equipment in America.* (G. R. Ward, Welding Industry, March, 1939, pp. 82-90. Metropolitan Vickers Tech. News Bulletin, No. 652, 17/3/39, p. 5.) (66/43 U.S.A.)

Developments considered in this article comprise equipments which produce faster and more efficient welding than the plant they supersede. The first of these developments is an improved type of multiple spot welder, in which the entire group of electrodes is brought into the pressure position simultaneously. A small machine for making a single row of 20 spots (having the advantages of simplicity, high welding tip life, and small transformer capacity) and a combination machine for welding wide strips of stock together before pickling are described. Rapid flash welding of aluminium wheel rims, a composite machine for motor car body construction, an installation for the spot welding of heavy plate, and an improved continuous tube welder are also fully detailed. The performance figures of each machine are included. Illustrated with 10 photographs.

*The Manufacture of Composite Metals by Carbon Arc Welding.* (R. E. Kinkead, Mech. World, 10/3/39, pp. 246-7. Metropolitan Vickers Tech. News Bulletin, No. 652, 17/3/39, p. 5.) (66/44 U.S.A.)

The usefulness of composite metals is a function of the quality of the bond between the component parts. The new process described is designed to work on ingots, slabs, or billets which are then processed by normal steelworks methods. In the experimental equipment employed, a Lincoln Tornado carbon arc head is mounted on the tool carriage of a planer. A furnace mounted on the bed is provided for preheating the slab. The head is rocked transversely to the direction of the planer travel to give uniform heat distribution and depth of alloy penetration. Excellent bond results are claimed for the method. Illustrated with three photographs.

*Elastic Properties of Cast Iron.* (A. I. Krynitsky and C. M. Saeger, Jr., Bur. Stan. J. Res., Vol. 22, No. 2, February, 1939, pp. 191-207.) (66/45 U.S.A.)

An optical method for measuring the deflection of cast-iron transverse-test bars during loading and up to the breaking strength has been developed. Transverse strength properties were determined on test bars made from three types of cast iron heated to the maximum temperatures of 1,400°, 1,500°, 1,600°, and 1,700°C. Test bars were vertically cast bottom-poured in green-sand moulds at 100°, 150°, 200°, and 250°C. above the liquidous temperature. Total, plastic, and elastic

deflection; modulus of rupture; modulus of relative elasticity; and total, plastic, and elastic resilience were determined and the microstructure of the test bars was examined.

The results of the transverse tests indicate that the initial portion of the elastic deflection curve is a straight line, but at approximately half of the breaking load the curve inclines towards the deflection axis. For all bars of iron *A* the points of inflection occurred at loads between 1,400 and 1,800 pounds, for irons *B* and *C* the limiting value lay between 1,200 and 1,400 pounds. Because of the curvature of the elastic deflection curves, a value for the relative modulus of elasticity, computed from the data for any point on the initial linear portion of the curve, is approximately 1,000,000 pounds greater than a similar value computed from the load and deflection at the point of rupture.

*The Intercrystalline Corrosion of Some Aluminium Alloys.* (J. D. Grogan and R. J. Pleasance, Engineer, Vol. 167, No. 4341, 24/3/39, p. 385.) (66/40 Great Britain.)

The intercrystalline failure under static stress of the aluminium alloy containing 3 per cent. copper and 20 per cent. zinc and of kindred alloys in the form of wrought heat-treated strip and the influence of heat treatment on the sensitivity of the alloys to such failure are examined. It is shown that the sensitivity increases with the quantity of zinc in solid solution. Attention is drawn to the similarity of failure in air to that in salt solution. The influence of heat treatment on this type of failure in thin strip "Y" alloy and 4 per cent. copper-aluminium alloy is examined. It is found that material rapidly cooled from the solution treatment temperature by quenching in cold water is free from inter-crystalline attack when submitted to sea-water spray, and that in this case corrosion is not influenced by the imposition of static tensional stress on the material during exposure. Material more slowly cooled, *e.g.*, in air, is susceptible to inter-crystalline corrosion, which is markedly stimulated by the imposition of static stress.

*Local Instability of Symmetrical Rectangular Tubes Under Axial Compression.* (E. E. Lundquist, N.A.C.A. Tech. Note No. 686, Feb., 1939.) (66/47 U.S.A.)

A chart is presented for the coefficient in the formula for the critical compressive stress at which cross-sectional distortion begins in a thin-wall tube of rectangular section symmetrical about its two principal axes. The energy method of Timoshenko was used in the theoretical calculations required for the construction of the chart. The deflection equation used in this method was selected to give good accuracy. The exact values given by solution of the differential equation were calculated for a number of cases and it was found that the energy solution was correct to within a fraction of 1 per cent.

The calculation of the critical compressive stress at stresses above the elastic range is also discussed. In order to demonstrate the use of the formulas and the chart in engineering calculations, several illustrative problems are included.

*Loads Imposed on Intermediate Frames of Stiffened Shells.* (P. Kuhn, N.A.C.A. Tech. Note No. 687, Feb., 1939.) (66/48 U.S.A.)

The loads imposed on intermediate frames by the curvature of the longitudinals and by the diagonal tension effects are treated. A new empirical method is proposed for analysing diagonal tension effects. The basic formulas of the pure diagonal tension theory are used, and the part of the total shear $S$ carried by diagonal tension is assumed to be given by the expression:—

$$S_{DT}=S\ (1-\tau_0/\tau)^n$$

where $\tau_0$ is the critical shear stress, $\tau$ the total (nominal) shear stress, and $n=3-\sigma/\tau$ where $\sigma$ is the stress in the intermediate frame. Numerical examples illustrate all cases treated.

*Metallic Materials for Thermocouples.* (A. Schulze, Wärme, 25/2/39, pp. 127-9. Metropolitan Vickers Tech. News Bulletin, No. 653, 24/3/39, p. 3.) (66/49 Germany.)

The author discusses metallic materials suitable for thermocouples. He deals first with the rare metals (platinum, rhodium, rhenium, iridium, etc.), and then with other metals and alloys (constantan, copper, silver, nickel, etc.). He indicates in particular the progress achieved in the field of the rare metal materials and, in the case of the second class of metals, shows the optimum attainable in regard to magnitude and sensitivity of the thermocouple electromotive force. Illustrated with three diagrams.

*The Deep-Drawing of Light Alloys for Aircraft Construction.* (E. J. Ritter, Luftwissen, Vol. 5, No. 7, July, 1938, pp. 249-255.) (66/50 Germany.)

After discussing the mechanical processes accompanying deep-drawing, the author examines the available light alloys as regards their suitability to this treatment. For this purpose a figure of merit has been developed which can be expressed in the form $m = d/D$

where $D$ = diameter of original plate,
$d$ = diameter of cup after drawing.

Representative values are $m = .6$ and $.8$ for the first and second drawing respectively.

It appears that modern light alloy plates (with the exception of pure aluminium) are seldom consistent and each plate should, therefore, be examined for its deep drawing qualities before the work is started.

After describing special test machines for this purpose, the author briefly discusses the various types of presses in use. In the case of relatively small production, very simple wood dies can often be employed.

Interesting photographs of examples of work turned out by the Junkers firm are given and a bibliography on the subject concludes the article.

*Surface Hardness and Type of Wear (Lead Preferable to Stellite in Certain Cases).* (Engineer, Vol. 167, No. 4343, 7/4/39, p. 433.) (66/51 Great Britain.)

When making feather dusters the feathers are drawn through a metal ring to regiment the quills. The tiny protective scales on the feathers wear out the ring in time, and this wear could not be prevented by using very hard rings made of stellite or carboloy. It is clear that hardness as measured by penetration of a steel ball bears no relation to the hardness as measured by the depth of groove of a diamond cutter. Prediction of wear under unusual conditions is thus impossible. In the present case the difficulty was overcome by utilising a lead ring. This material stands up indefinitely under these particular conditions, the metal apparently flowing backwards and forwards under the action of the feather scales. In the case of the harder material, however, minute particles of the metal break off.

*The Influence of Internal Stresses on the Resistance of Metal to Cutting and Wear.* (N. N. Sawin, Machinery, 23/3/39, pp. 802-5. Metropolitan Vickers Technical News Bulletin, No. 654, 31/3/39, p. 5.) (66/52 Great Britain.)

The article gives the results of extensive tests which tend to show that the cutting of metal requires less energy if internal stresses are present as a result of previous treatment, than under precisely similar conditions with such stresses removed by annealing. The mechanical work expended in cutting, with a given feed, on standard untempered material was compared with that taken in the cutting of previously tempered steel. Abrasive wear in the material is shown to occur more rapidly if surface stresses exist. Abrasive tests on various types of

steel by the Skoda-Sawin wear testing machine, in conjunction with heat treatment, are fully detailed and the results correlated by graphical means. Illustrated with six diagrams.

*Monocoque Fuselage Circular Ring Analysis.* (B. F. Ruffner, J. Aeron. Sci., Vol. 6, No. 3, January, 1939, pp. 114-6.) (66/53 U.S.A.)

A method of solving for stresses in a uniform circular ring loaded with concentrated loads which are held in equilibrium by the distributed reactions in the fuselage is described. Formulæ giving the shear, direct force, and bending moments in a ring loaded with a pair of symmetrically placed concentrated loads are derived. It is indicated how these formulæ may be applied to cases where several pairs of symmetrically placed concentrated loads are acting.

*Materials for Aeroplane Construction.* (J. B. Johnson, J. Aeron. Sci., Vol. 6, No. 5, March, 1939, pp. 185-202.) (66/54 U.S.A.)

There are no materials used in aircraft construction which are not adaptable to other fields of engineering. Speaking generally, high tensile steels are preferable for elements subjected to tensile loads only and low density alloys are comparable to steel for structural elements subjected to flexural loads where there is no restriction on dimensions or form.

The majority of failures on aircraft are, however, produced by fatigue and it appears in this connection that the basic fatigue limit is of secondary importance compared with amplitude and frequency control effected by correct combination of structural rigidity and plasticity. For this reason direct vibration tests on built-up assemblies simulating practical conditions are becoming more general.

The author reviews the various aircraft materials in use at the moment. Only two new materials have recently become available: Compressed (impregnated) wood and synthetic resins.

The former is already receiving a wide application in the construction of propeller blades. Too little is as yet known about the fatigue limits of synthetic resins (*i.e.*, plastics) to forecast their possible application for primary structural components. For minor fittings and also in the form of transparent sheet a useful field of application is, however, already assured.

*Combating Corrosion in Design and Construction.* (R. S. Barnaby, J. Aeron. Sci., Vol. 6, No. 5, March, 1939, pp. 211-15.) (66/55 U.S.A.)

A study of the maintenance of large aluminium alloy flying boats makes it clear that corrosion is still a major problem. This corrosion is not general, but in isolated spots and associated with unsealed crevices, undrained pockets, and dissimilar materials. If a reasonable service life is to be obtained, corrosion prevention must start on the drafting board and continue throughout the design and construction of the aeroplane. The rules are:—(1) fill the crevices; (2) drain the pockets; (3) keep dissimilar materials apart.

*The True Velocity of Sound in Air.* (H. O. Kneser, Ann. d. Physik, Vol. 34, No. 7, April, 1939, pp. 661-668.) (66/56 Germany.)

The author reviews the more accurate recent velocity determinations and points out that certain discrepancies can be accounted for by the roughness of the surface along which the sound is propagated. This effect becomes especially marked if the distance from the wall is of the same order as its wavelength. The most probable value for the true velocity of sound (determined from frequency and wavelength, *i.e.*, $V = n\lambda$) appears to be $331.60 \pm .05$ m. for dry air at 0°C. and zero $CO_2$ content.

Over woodland the apparent speed under otherwise similar conditions may be as low as 330.67 m.

*Problems of Periodic Heat Transfer with Special Reference to Reciprocating Engines.* (H. Pfriem, Forschung, Vol. 10, No. 1, January-February, 1939, pp. 27-40.) (66/57 Germany.)

Heat transfer from a gas to a wall is largely a question of conduction through the boundary layer. This transfer takes time and as a result there exists a phase displacement between gas and wall temperature if the former undergoes periodic variations. The author proposes a new definition for the heat transfer coefficient which takes this time lag into account and applies this concept to the study of four fundamental cases:—

1. Steady flow of gas in a heat-insulated tube, the gas experiencing a periodic temperature variation at the inlet.
2. Periodic flow at constant temperature of gas core.
3. Effect of combustion at constant pressure on heat transfer.
4. Effect of pressure changes on heat transfer.

The heat transfer in an engine cylinder is a combination of the above four cases and thus necessarily very complex. It is, however, hoped that theoretical studies of this nature will ultimately lead to methods of heat flow control which would be extremely valuable during the take-off of heavily loaded aircraft engines.

*The Measurement of Rapidly Changing Cylinder Wall Temperatures.* (A. Meier, Forschung, Vol. 10, No. 1, January-February, 1939, pp. 41-54.) (66/58 Germany.)

Cylinder wall temperatures have so far been measured with thermocouples. This method suffers from the drawback that the couple can only be placed at some distance from the wall. The measured temperature field has, therefore, to be corrected for damping and phase displacement and this together with the small value of the original thermal E.M.F.'s renders the final estimate rather uncertain. Pfriem has developed a resistance thermometer consisting of a thin layer of gold deposited on the end of a plug which is inserted in the cylinder and terminates flush with the inside wall. The thickness of the layer is of the order of $2 \times 10^{-3}$ mm. and its temperature lag is negligible. The sensitivity of the circuit adopted is about 100 times that of the usual thermocouple circuit (*i.e.*, $de/dt = 6 \times 10^{-3} V/°C.$ against $.05 \times 10^{-3} V/°C.$).

Oscillograph records can thus be taken without previous amplification.

Carbon deposits on the wall reduce the temperature variation very materially. Thus in the case of a small two-stroke engine operating at 2,000 r.p.m. the cyclic wall temperature jump amounted to over 10°C. with the engine freshly cleaned. After 20 hours this fluctuation was reduced to less than 5°C. with a corresponding reduction in mean wall temperature from 200°C. to 190°C.

*A Sense Finding Device for Use with Spaced Aerial Direction Finders.* (R. A. Fereday, J. Inst. Elec. Eng., Vol. 84, No. 505, January, 1939, pp. 96-100.) (66/59 Great Britain.)

A simple method is described for the rapid determination at a receiver of the sense of the direction of arrival of radiation from any transmitting station. A radio bearing of the station is taken in the usual manner with a four-aerial Adcock direction-finding system, and a second observation of minimum received signal is made after certain modifications to the electrical connections between the aerials have been effected by switching. The two observations are sufficient to determine without the usual ambiguity of 180° the bearing of the transmitting station at the receiver. The method is particularly suitable for use on high frequencies and with the visual type of receiver incorporating a cathode-ray tube.

*A Terrain Clearance Indicator.* (L. Espenschied and R. C. Newhouse, J. Aeron. Sci., Vol. 6, No. 4, Feb., 1939, pp. 137-41.) (66/60 U.S.A.)

The method used in the present instrument is extremely simple in theory. A radio transmitter is provided on the aeroplane which sends toward the earth a signal, the frequency of which changes at a definite rate with respect to time. The signal is reflected by the earth and returns as an echo after a time delay equal to twice the height, divided by the velocity of propagation. During this interval the frequency of the transmitter has changed and now differs from that of the echo by an amount equal to the product of the rate of change of frequency and the time of transit. The reflected wave is combined in the plane receiver with some of the out-going wave energy and the difference or " beat " frequency is measured by a frequency meter. Since the reading of the meter is that of the " beat " frequency, it is proportional to the time delay of the echo and, hence, to height and thus can be calibrated directly in feet.

*Television Principle Applied to Blind Landing by the R.C.A.* (Inter. Avia., No. 631, 31/3/39, p. 1.) (66/61 U.S.A.)

As the aircraft approaches the field an image is transmitted revealing to the pilot the name of the field, the direction of the wind, the barometer and other information. This image is picked up by the receiver and made visible on part of the television screen. In the vicinity of the landing field the aircraft runs into the reach of the short wave transmitter. The latter transmits a beam focused like the light of a searchlight. This beam is elevated and swung around until it hits the aircraft circling the field, and is picked up by the latter's receiver. The beam comprises radio impulses which are automatically varied in frequency to correspond with the angle along which a safe landing is to be made.

The receiver on the aircraft is so adjusted that it picks up those radio impulses whose frequency corresponds to the desired gliding angle of the aircraft. The reception of these impulses is also transmitted to the television screen in the form of a series of oblique lines of the same angle as the gliding beam. The lines remain constantly visible as long as the aircraft remains on the proper glide patch; should it stray from it their angles vary correspondingly and they fade at the same time, disappearing altogether in the case of greater deviations.

" *Klystron* " *Ultra-High Frequency Generator Applied to Blind Landing Beams (Horn Projector).* (Inter. Avia., No. 631, 31/3/39, pp. 2-3.) (66/62 U.S.A.)

A beam of electrons representing a constant current is sent through two metal containers acting as resonators and known as Rhumbatrons. In the first Rhumbatron is an oscillating electric field, parallel to the stream and of such strength as to change the speeds of the electrons by appreciable fraction, accelerating some and slowing down others. After passing through the first Rhumbatron the accelerated electrons begin to overtake those with decreased speeds ahead of them. This motion groups the electron into bunches separated by relatively empty spaces. In the second Rhumbatron—which contains a synchronously oscillating electric field—a considerable fraction of the power of the arriving electron bunches is converted into power of high frequency oscillations.

The first Rhumbatron of the Klystron is called the " buncher," the second the " catcher." The name Klystron comes from the Greek verb " klyzo " denoting the breaking of waves on a beach. The originally not seriously intended " Rhumbatron " was retained as the scientific name in view of its likeness to the Greek word " rhumba " for rhythm in motion.

The Klystron acts as:—an amplifier if the buncher is driven by an external source of power such as a receiving antenna; as an oscillator if the buncher is coupled to the catcher; and as a regenerative amplifier if the buncher is driven by power from both these sources.

## LIST OF SELECTED TRANSLATIONS.

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Lists of selected translations have appeared in this publication since September, 1938.

### AERODYNAMICS AND HYDRODYNAMICS.

| TRANSLATION NUMBER AND AUTHOR. | TITLE AND JOURNAL. |
|---|---|
| 851 Maletzke, R. ... ... | *Meteorological Fundamentals for Flying in the Alps.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 325-8.) |
| 852 Pretsch, J. ... ... | *The Theoretical Calculation of Profile Drag.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 60-81.) |

### AIRCRAFT AND ACCESSORIES.

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| 853 Stiesz, W. ... ... | *Effect of the Direction of Rotation of the Airscrews on the Longitudinal Stability of Twin-Engined Aircraft.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 206-19.) |
| 856 Isermann, R. ... Beck, E. ... ... | *Take-off by Running Down a Steep Slope.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 306-12.) |
| 859 Weinig, F. ... ... | *Static Thrust Measurements on Large Propellers.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 404-9.) |
| 860 Seiferth, R. ... ... | *Wind Tunnel Investigations on the Effect of Direction of the Airscrews on the Longitudinal Stability of the Twin-Engined Aeroplane.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 220-5.) |
| 861 Sydow, J. ... ... | *The Effect of Spring Support and Reeling on Landing Impact.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 329-38.) |

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|---|---|
| 716 Cmekalov ... ... | *Training Device for Firing at Aerial Targets.* (Air Fleet News, U.S.S.R., Vol. 18, No. 12, December, 1936, pp. 19-20.) |
| 748 Krotkov ... ... | *Target Cone of Dimensions* $2 \times 8$ *m.—Its Preparation and Use.* (Air Fleet News, U.S.S.R., Vol. 20, No. 1, January, 1938, pp. 46-52.) |
| 815 Barichello, M. ... | *The Motion of a Projectile about its Centre of Gravity.* (Rassegna di Cultura Militare, Vol. 1, No. 3, March, 1938, pp. 191-213.) |

## Materials and Elasticity.

| Translation Number and Author. | | | Title and Journal. |
|---|---|---|---|
| 575 | Zolotarev, H. C. | ... | *Stress Analysis of Engine Elements.* (Aeron. Eng. (U.S.S.R.), No. 4, April, 1937, pp. 48-60.) |
| 850 | Leysieffer, G. | ... | *Synthetic Materials and Their Application.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 554-60.) |
| 854 | Marguerre, K. | ... | *The Longitudinal Load Capacity of a Plate After the Bulging Load has been Exceeded.* (Jahrbuch der Deutschen Luftfahrtforschung, 1937, Vol. 1, pp. 421-9.) (Z.A.M.M., Vol. 17, No. 2, 1937, pp. 85-100.) |
| | Trefftz, E. ... | ... | |
| 855 | Pucher, A. ... | ... | *The Fields of Influence of the Moments of Rectangular Plates.* (Thesis, Berlin Technical College—Published by W. Ernst and Son, 1938.) |
| 858 | Marguerre, K. | ... | *Application of the Energetic Method to Problems of Stability.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 433-43.) |
| 863 | Kahlisch, W. | ... | *Calculation of the Stiffening Rings in Cylindrical Shells in the Case of Local Application of Large Loads.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 457-60.) |

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| 862 | Dieckmann, M. | ... | *Investigations of Wireless Direction—Finding Loops Placed Inside Metal Aircraft.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. 3, 1938, pp. 59-62.) |
| | Barner, K. ... | ... | |
| 864 | Harmening, E. | ... | *Suitability of 3 m. Wireless Waves for Direction Finding.* (Jahrbuch der Deutschen Luftfahrtforschung, 1938, Vol. 3, pp. 63-5.) |
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## Miscellaneous.

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| 630 | —— ... | ... ... | *Report of the German Committee of Investigation into the Accident of the Airship "Hindenburg" on 6/5/1937, at Lakehurst, U.S.A.* (Luftwissen, No. 1, January, 1938, pp. 3-12.) |
| 849 | Vetchinkin, V. P. | ... | *The Method of Simultaneous Similar Azimuths for Determining Latitude and Time Correction.* (All Union Scientific Technical Press, U.S.S.R., 1937.) |

## ABSTRACTS OF PATENT SPECIFICATIONS.

*(Specially abstracted for the Journal by W. O. Manning, F.R.Ae.S.)*

Abstracts of Patent Specifications received by the Society are published in the Journal. It should be noted that these abstracts are specially compiled by Mr. W. O. Manning, F.R.Ae.S., for the Journal and are only of those actually received and subsequently bound in volume form for reference in the library. These volumes extend from the earliest aeronautical patents to date, and form a unique collection of the efforts which have been made to conquer the air.

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AEROFOILS.

496,372. *Improvement in Aerofoils.* Craigon, A., 307, Garden Avenue, Toronto, Canada. Convention date (U.S.A.), May 17th, 1937.

The aerofoil consists of a basic wing with fixed chord span and camber and a number of spanwise slidable telescoping wing surfaces or covers of greater camber than the basic wing, but having nearly the same mean chord and superimposable only on the upper surface of the basic wing whereby more or less of the upper surface only of the basic wing may have surfaces of greater camber superimposed thereon, leaving the under surface unaffected and substantially without increasing the area of the aerofoil. One object of this arrangement is to produce a wing which is adjustable at the will of the pilot to suit best the take-off conditions, etc.

AEROPLANES.

500,541. *Improvements in and relating to Aeroplanes.* Hamburger Flugzeugbau G.m.b.H., Hamburg, 1, Germany, and Vogt, R., 13, Oderfelderstrasse, Hamburg, 37, Germany. Dated Dec. 28th, 1937. No. 10,719.

This is an unsymmetrical aeroplane having the single engine nacelle and the fuselage side by side, placed respectively on each side of the centre line of the machine. In order to compensate for the unsymmetrical thrust, the airscrew may be at an angle to the longitudinal axis of the machine, or a rudder unit in the slipstream may be given an appropriate angle or the leading edge of the tail unit may be caused to form an acute angle with the axis of thrust of the airscrew. Any combination of these methods may be used.

AIRCRAFT—CONSTRUCTION.

498,516. *Improvements relating to Combined Mechanical and Fluid Operated Controlling Means.* Dowty, G. H., Arle Court, Cheltenham, Gloucestershire. Dated June 8th, 1937. No. 15880.

The proposed control means for aircraft wings, flaps, etc., comprises a member capable of resisting tension, borne to resist loads transverse to its length and

guided for longitudinal movement. A fluid-operated jack is constructed thereto so that the member may be moved in either direction. The tension member is preferably connected to the flap by a number of short rigid links. The tension member may be made up of short lengths of rod, light tube inter-connected by joints permitting misalignment.

498,063. *Improvements in Aircraft Fuselage and Like Metallic Constructions.* Renault, L., 8, Avenue Emile-Zola, Billancourt (Seine), France. Convention date (France), Oct. 7th, 1936.

It is proposed to cover fuselage structures with thin metal plates which are first subjected to tension. The main structure is formed of frames to which the sheet metal covering is welded or riveted. The longitudinal members pass loosely through the frames, are secured to the end frames, but are not attached to the covering which latter is tensioned after assembly.

497,766. *Improvements in and relating to Light Structures.* Schmid, A., Finkenstrasse 13, Berlin-Dahlem, Germany. Convention date (Germany), July 9th, 1936.

It is proposed to construct structural members by using as the structural material, circular, polygonal, or other tubular elements made of a cellulose derivation and stuck together by means of a solvent. Metal wires or gauze can be embedded in the material. Apart from being stuck together in a bundle with their axes parallel, the components may be attached in an angle or by cross connecting pieces so as to form a composite structure. They may also be enveloped in sheeting of the same or other material.

497,969. *Improvements in or relating to Aircraft.* Handley Page, Ltd., 40, Claremont Road, Cricklewood, Middlesex, and Lachmann Balla, Commons Drive, Canon's Park, Middlesex. Dated July 2nd, 1937. No. 18,426.

This is a tailless aeroplane which has a front elevator in advance of the leading edge of the wing and of the centre of gravity. This aerofoil is freely pivoted so that it preserves a nearly constant angle of incidence, but is at the same time under the pilot's control. The front elevator may have a trimming tab and this tab may be interconnected with flaps on the wing so as to counteract the pitching moment caused by lowering the flaps.

498,010. *Improvements in Flying Machines.* Swingle, E. L., Sawyers Hall Cottages, Brentwood, Essex, England. Dated June 29th, 1937. No. 18,021.

The proposed flying machine has a tilting frame extending across over the oblong frame and carrying lifting airscrews between its edges, one at each side. There is one tilting wing in front of and another behind the tilting frame, two sets of control gear, one of which controls the wings and tilting frame, the other controls the steering.

497,500. *Improvements in or relating to Aeroplanes.* Rose, W. K., 250, Riverside Drive, City and State of New York, U.S.A. Convention date (U.S.A.), Nov. 10th, 1936.

This describes an aeroplane wing which has a number of vanes forming passage-ways between the upper and lower surfaces, the cross section of the passage-ways gradually diminishing from the inlet to the outlet, the passage-ways being curved with its mean line a segment of a flat spiral. The mean lines of the inlet and outlet posts of the passage-ways form an angle of about 90 degrees with each other. Means are provided for controlling the extent to which the passage-ways are open and for closing them.

497,623. *Improvements in or relating to Aircraft Wing Construction.* Deekay Aircraft Corporation and Hart-Still, S. C., both of 39-40, Albemarle Street, London, W.1. Dated June 21st, 1937. No. 29,528.

This is a stressed skin wing of plastic material of multi-cellular type with the cells extending spanwise. There are thin vertical sheet members with enlarged sections at top and bottom, these, with top and bottom horizontal members, complete the cells. The plastic used may be a synthetic resin combined with a cellulose fluff, or the resin may be of the phenol type. The vertical members are parallel and are of the full depth of the structure, while the horizontal members are of aerofoil shape.

500,076. *Aerofoil Structure.* Barkley, A. St. C., 318e, Grand Boulevard, Detroit, Michigan, U.S.A. Dated Jan. 12th, 1938. No. 1,030.

The wing structure proposed has longitudinally fluted sheet steel metal segments secured together and arranged to form a series of closed polygonal or circular passages extending lengthwise; reinforcing members are secured to the upper and lower stressed skins and to the segments. The segments have their opposite edges bent back towards each other forming a series of laterally spaced longitudinally extending triangular cells.

499,068. *Improvements in and relating to Wings, Control Surfaces, Rudders, and the Like of Aircraft.* Junkers Flugzeug-und-Motorenwerke Aktiengesellschaft, 39, Junkersstrasse, Dessau, Anhalt, Germany. Convention date (Germany), Feb. 8th, 1937.

The parts are formed by box type girder supports, the width of which occupies a considerable portion of the chord of the member and which are divided longitudinally. The two parts are detachable. The effect is to provide a stable rigid body. The upper and lower boundary walls of the box are formed by buckling and bending resistant upper and lower longitudinal walls over a considerable zone of the chord.

496,003. *Improvements in or relating to Folding Wing Aircraft.* The Fairey Aviation Co., Ltd., North Hyde Road, Hayes, Middlesex, and Trotter, J. C., 2, Manor Parade, Hillingdon, Middlesex. Dated Nov. 30th, 1937. No. 33,094.

In the case of low wing monoplanes where folding is carried out by means of a vertical hinge between the wing and the fuselage, an inner portion of the rear part of the wing is adapted to be folded over the wing itself. This inner portion is adapted to be swung about its hinge by means of a pair of links which are pivoted together and which are also pivoted respectively, the one to the main portion of the wing and the other to the inner portion. A screw jack may be mounted so as to act on these links, or they may be operated by a screw jack by hand.

496,161. *Improvements in or relating to Folding Wing Aircraft.* The Fairey Aviation Co., Ltd., North Hyde Road, Hayes, Middlesex, and Lobelle, M. J. O., Ludlow, 298, Langley Road, Langley, Bucks. Dated Nov. 30th, 1937. No. 33,095.

In the case of a monoplane wing hinged for folding by a vertical hinge, a part of the inner rear portion of the wing can fold over or under the wing itself, the rear portion of the wing can be raised or lowered by pushing action of the one or the other of two levers of the first order with one arm of which the flap is connected, said lever being pivotally mounted on said portion of the wing, and said rods being slidably mounted on the stub of the wing or a part carried thereby.

492,796. *Improvements in or relating to the Construction of Aircraft and Other Vehicle Bodies, Containers, or Other Light Hollow Bodies.* Klemm, H., Waldurgstrasse 29, Boblingen, Germany. Convention date (Germany), Nov. 5th, 1936.

It is proposed to make fuselages, etc., by making partial sections which are manufactured independently and then joined together. For manufacturing a partial shell, cut along one of the longitudinal sections of the body, stiffening members or cross frames are first inserted in a mould and the skin parts stretched over and secured on the stiffening members. The partial shell is then removed from the mould and joined to others by means of their stiffening members.

490,964. *Improvements in or relating to Folding Wing Aircraft.* The Fairey Aviation Co., Ltd., North Hyde Road, Hayes, Middlesex; Lobelle, J. O., Ludlow, 298, Langley Road, Langley, Bucks; and Trotter, J. C., 2, Manor Parade, Hillingdon, Middlesex. Dated May 22nd, 1937. No. 14,330.

The folding trailing marginal portions of an aircraft wing, including flaps, are supported by triangular brackets which are hinged at one corner or near one corner of the upper surface of the wing and are detachably secured at another corner or near the other surface of the wing, while a third corner forms a pivot about which the flap rotates. The operation of the flap may be effected by means of a hydraulic jack connected at one end with the rear of the flap and at the other end with the rear of the folding portion. Preferably the folding of the marginal portion is effected with the flap in its lowered position and means may be provided which straighten the flap during the folding operation.

494,177. *Improvements in Variable Camber Wings.* Grant, C. H., 166, Centre Avenue, New Rochelle, Westchester, New York, U.S.A. Convention date (U.S.A.), May 6th, 1936.

The proposed wing is rigid except for the trailing edge which has a number of separate sections pivotally inter-connected which are free to rotate the members curving downwards so as to act as a flap. The means for operating are situated below the pivotal connections of the members.

494,233. *Improvements in or connected with the Construction of Wings, Fuselages, or Other Aircraft Bodies.* Vickers (Aviation), Ltd., and Wallis, B. N., both of Weybridge Works, Brooklands Road, Weybridge, Surrey. Dated April 21st, 1937. No. 11,381.

This is a method of arranging the geodetic members so that it is no longer necessary to interrupt them on the longitudinal members. The geodetic members extend uninterruptedly past the places where the longitudinal members are placed, and the bracing members are apertured to allow the longitudinal members to be threaded through them, the parts being fixed together by means, say, of a pin. The longitudinal members are of greater depth than breadth.

AIRSCREWS.

499,622. *Improvements in or relating to Apparatus for Driving Co-axial Propellers in Opposite Directions.* Aeroplani Caproni Societa, Anonima, 76, Via Caio Clino Mecenate, Milan, Italy. Convention date (Italy), March 25th, 1937.

The propellers are driven by normal reduction gears, but in the drive to one of them there is interposed an arrangement of three mutually intermeshed bevel gears which reverse the direction of rotation. The lubricating oil, after passing through the oppositely rotating parts is collected in the form of a centrifugally produced annulus and means are provided for tapping oil from the annulus and returning it to the supply. This tapping is effected by means of a radial nozzle rotating in a direction opposite to that of the annulus.

496,278. *Improvement in the Propulsion of Aircraft.* Killen, J. W., Knockmore, Lawrence Hill, Londonderry, and Usher, H. A., 12, Heath Drive, West Wimbledon, London, S.W.20. Dated May 28th, 1937. No. 14,790.

This describes a propeller in which the blade or blades are arranged to be tilted at definite regions in their rotary path about the axis of the driving shaft, comprising a blade carrying shaft arranged at a right angle to the axis of the driving shaft so mounted on the end of the driving shaft that it is capable of limited longitudinal motion and is provided with a screw-threaded element which engages a relatively fixed nut element on the driving shaft, provision being made whereby the blade-carrying shaft has imparted to it an axial reciprocating motion whereby the nut and screw impart to it an oscillatory rotary movement during which the blades are tilted in the desired manner.

ARMAMENT.

497,938. *Aerial Forts.* Jones, T. B., Gwessin Villa, Tregoos, Llandyssul, Cardiganshire. Dated June 28th, 1937. No. 17,902.

The aerial fort is intended to be elevated over cities for anti-aircraft protection, and it consists of two frames, one of which is connected to the ground by a cable and the other frame is hinged to the first and carries electric motors driving lifting airscrews. The first frame is hinged to the other at a point above its centre of gravity so that a horizontal component of the thrust is automatically introduced to counteract drift. The second frame may carry personnel and equipment.

494,256. *Improvements in or relating to Aeroplanes.* Redgrave, K., and Scottish Aircraft and Engineering Co., Ltd., both of Scotia Works, Hythe Road, Willesden, London, N.W.10. Dated April 23rd, 1937, No. 11,701, and April 23rd, 1937, No. 11,702.

In the case of aircraft having bodies with external contours designed to augment the lift of the machine, it is proposed to arm such machine with guns approximating to 37 mm. bore, and to mount these guns in retractable turrets at the stem corners of the main framework. The turrets are rotatable in housings and the guns may protrude above or below the machine. Alternatively, a single gun may be disposed centrally.

494,222. *Improvements in or relating to the Armament of Aeroplanes.* Cook, F., 51, Pickering Road, Hull, Yorks. Dated May 30th, 1938. No. 16,066.

It is proposed to mount guns to fire laterally, the guns being operated by such means as Bowden cables, there being provided a sighting device by means of which the gunner can follow the field of view traversed by the guns as a result of manœuvring the aeroplane so that the gun can be trained on a target. The guns are to be mounted horizontally sideways on each wing, usually at the wing tip, though in certain cases they may be within the fuselage. The sighting device may be a form of periscope.

CONTROL OF AIRCRAFT.

497,953. *Improvements in Gyroscopes.* Societe Civile d'Etudes de Constructions Aeronautiques (E.C.A.), 3, rue Saint Georges, Paris, France. Convention date (France), June 30th, 1936.

This is a device for the automatic stabilisation of vehicles, especially aeroplanes, and also for indicating the velocity of a movement caused by a disturbance. The apparatus is utilised for angularly moving the frame of a precession gyroscope, this movement being used for control.

497,509. *Improvements in or relating to Aircraft Landing Flaps and Control Surfaces.* Dornier-Werke G.m.b.H. and Dr. Ing. C. Dornier, both of Friedrichshafen, Lake Constance, Germany. Convention date (Germany), Dec. 5th, 1936.

This is an apparatus for controlling aircraft flaps and control surfaces so that each member, when at rest, forms a continuous profile with the wing. Each flap or control comprises two or more members rotatable about a common axis which, when they are operated, is controlled in such a manner that the member lying in the direction of flight is always within the wing. The gear used is self-locking.

499,503. *Improved Hinge Mechanism for the Moving or Control Surfaces of Aircraft.* Tampier, R., 1, rue de Bellevue, Boulogne-sur-Seine, France. Dated July 29th, 1937. No. 21,015.

It is proposed to provide a casing, a lever, or hinge arm secured on a shaft rotatably mounted on bearings at one end of the casing. A control lever is fixed to a shaft at right angles to the first shaft mounted on bearings at the opposite end of the casing. Cranks extend from each shaft within the casing and their ends are connected by, for example, ball joints attached to a third member.

499,632. *Improvements in Aircraft Designed to Facilitate Take-off and Landing.* Hammond, E. V., 88, Louisville Road, Balham. Dated April 14th, 1938. No. 11,470.

A normal aeroplane is provided with a retracting rotor for giving additional lift while the normal stabilising parts of the aircraft are modified so as to confer the stability necessary. These modified or additional means of stability coming into action when the rotor is extended from its housing and going out of action when the rotor is retracted. The retraction or extension of the undercarriage may also be operated in conjunction with similar operations to the rotor. The rotor may have only one blade.

499,833. *Improved Means for Controlling the Moving Surfaces of Aircraft.* René Tampier, 1, rue de Bellevue, Boulogne-sur-Seine, France. Dated July 29th, 1937. No. 21,016.

This specification refers to variable contour aerofoils or control surfaces which it is proposed to make in several parts and to hinge them together in tandem relative movement of the parts being effected by axially slidable members which move along the hinge axes. The transmitting means between each pair of hinges consists of the axially slidable member and a mechanical transmission consisting of bell-crank levers operatively connecting the displaceable members.

495,876. *Improvements in or relating to Means for Controlling and Trimming Aircraft.* Brown, D. B. W., Dobbs Ferry, Westchester County, New York, U.S.A. Convention date (U.S.A.), July 25th, 1936.

In order to overcome the propeller torque of aircraft use may be made of the horizontal tail control surfaces by operating them differentially or in unison. When operated differentially a rolling moment is produced; they are operated in unison for control. These control means have been devised specially for use with two co-axial airscrews carried by concentric shafts rotating in opposite directions and are brought into operation when one engine stops or is working at lower power than the other. They may, however, be used with any type of engine arrangement where an engine torque acts on the aeroplane.

496,054. *Improvements in Controls for Aircraft.* Andrews, W. R., and Scottish Aircraft and Engineering Co., Ltd., both of Scotia Works, Hythe Road, Willesden, London, N.W.10. Dated May 26th, 1937. No. 14,635.

This arrangement relates to controls having a large pivoted surface operated by the pilot and a smaller auxiliary movable surface mounted on the large surface and operated with it. The main control surface has a portion of its chord projecting in front of its hinge so that it is inherently unstable, the smaller surface is hinged to the main surface at a point behind the hinge of the latter. The main surface is controlled by the pilot through a device which allows automatic movement of the main surface owing to its inherent instability and additional to the hand control a mechanism for operating the auxiliary surface independence on the movements of the operating member and main control surface so as to control the automatic movement.

494,257. *Improvements in Control Devices for Aircraft.* Andrews, W. R., and Scottish Aircraft and Engineering Co., Ltd., both of Scotia Works, Hythe Road, Willesden, London, N.W.10. Dated April 23rd, 1937. No. 11,706.

This specification describes an irreversible control. A gearbox is interposed between the pilot and the control which contains multiplying gearing having a driving wheel operated manually and a driven wheel engaging by means of a screw with an axially movable shaft. The movements of this are communicated by means of a link to a rocking lever on the gearbox, this lever being coupled to the control to be operated.

496,153. *Improved Arrangement of and Locking Devices for Aircraft Control Levers.* Tampier, René, 1, rue de Bellevue, Boulogne-sur-Seine, France, Dated Aug. 28th, 1937. No. 23,605.

The arrangement consists of mounting an assemblage of pivoted levers loosely on a shaft, and providing each lever with a friction surface adapted to co-operate with a friction surface on a fixed member. The assembly can be compressed axially so as to regulate the frictional resistance and there are further means for so increasing the friction as to lock the levers. The means for compressing the assembly may consist of a screwed hand wheel, and the assembly may be locked by means of a hand lever fixed on a nut which is arranged to engage the thrust transmitting member.

496,522. *Improvements in or relating to the Control Surfaces of Aircraft.* The Fairey Aviation Co., Ltd., North Hyde Road, Hayes, Middlesex, and Trotter, J. C., 2, Manor Parade, Hillingdon, Uxbridge, Middlesex. Dated Oct. 2nd, 1937. No. 26,733.

The wing has a flap which is provided with a spoiler which is brought into action automatically when the flap is lowered beyond the position corresponding with maximum lift. The spoiler then closes the gap between the undersurface of the wing and the leading edge of the flap. The spoiler is connected to the trailing edge of the wing and is connected with link and lever mechanisms so disposed that when the flap has been lowered to the position of maximum lift the spoiler acts as desired.

496,526. *Improved Mechanism for Actuating the Control Surfaces of Aircraft.* The Fairey Aviation Co., Ltd., North Hyde Road, Hayes, Middlesex, and Trotter, J. C., 2, Manor Parade, Hillingdon, Middlesex. Dated Dec. 1st, 1938. No. 33,988.

In order that a wing flap may be lowered from its normal retracted position to a position below the wing and at the same time rotated to the desired angle about a point near the centre of pressure, the flap is carried by pivoting to the rear ends a pair of beams carried in turn by the wing through a pair of links

pivotally connected with the wing and with the beams at an intermediate point and through the medium of a jack mounted on the wing and connected with the front ends of the beams. Operating the jack provides the desired action of the flap.

496,609. *Aeroplane Flight Control.* The Glenn L. Martin Co., Middle River, Baltimore, Maryland, U.S.A. Convention date (U.S.A.), Dec. 16th, 1936.

The proposed flap is spaced from the wing by a slot, which latter can be obstructed by a shutter mechanism, including differentially operable mechanism for positioning the shutter to open the slot upon the adjustment of the flap from a high speed position. The shutter closes the slot so long as the two elements are in a substantially aligned position and in the train of elements for opening the flap there are a number which continue to move with the adjustment of the flap while the adjustment of the shutter is being completed.

496,875. *Improvements in Means for Controlling the Movements of Ailerons, Rudders and Elevators of Aircraft.* Tampier, René, 1, rue de Bellevue, Boulogne-sur-Seine, France. Dated May 6th, 1937. No. 12,947.

Control movements are effected by means of a screwgear comprising a screw and a nut. The axial travel of the nut along the screw is converted into a rotary movement which is then applied to the control surface. The proposed arrangement of this type is a device arranged so that it can be used as a hinge. A frictional arrangement is provided for the purpose of damping out vibrations and the arrangement generally is irreversible.

497,074. *Improvements in or relating to Lift-Increasing Devices for Aeroplane Wings.* United Aircraft Corporation, 400, South Main Street, East Hartford, Connecticut, U.S.A. Convention dates (U.S.A.), June 12th, 1936, and Aug. 4th, 1936.

Between the wing and the flap a slot is provided in which a deflector plate is located near the exit so that its leading edge projects into the slot. This deflector plate moves with the flap so as to extend and curve the wing slot so as to cause it to discharge air over the upper surface of the flap. The deflector plate may be so arranged so as to divide the slot into two portions, one of which always discharges the air in a fixed position with regard to the flap. A door may be used for closing the wing flap.

490,850. *Improvements in Aircraft Flaps.* Marenday, D. M. K., Barton Airport, Barton, Bedfordshire. Dated Feb. 13th, 1937. No. 4,321.

The combination of an aircraft wing with a flap or set of flaps normally housed within the wing and movable either into a position to increase the drag or into a position to increase the lift. There is an auxiliary aerofoil beneath the main wing at a point other than the trailing edge, adjustable from the folded position into a position where it is below and distant from the wing. The flap may be hinged to one of the wing spars and may be of true aerofoil section.

495,711. *Improvements in Distributing Apparatus for the Control of Two or More Distinct and Concomitant Devices.* Mercier, J., 131, Boulevard de la Seine, Neuilly-sur-Seine, Seine, France. Dated May 13th, 1937. No. 13,525.

This is a device for the simultaneous control by means of a fluid of distinct devices, such as flaps, split flaps, ailerons, brakes, etc. There is a cylinder with lateral openings for the inlet, the outlet, and the distribution of the fluid, and a slide valve member, balanced in the lateral and longitudinal directions, the valve being connected to the control member of the aircraft and arranged to follow the

movements thereof, provided in the case where a disturbance occurs in the symmetrical motion of distinct devices for the correction of this result by separating or connecting the inlet or outlet with the conduit controlling one of the aforesaid distinct devices.

494,110. *Improvements in or relating to Controls for Aircraft.* Andrews, W. R., and Scottish Aircraft and Engineering Co., Ltd., Scotia Works, Hythe Road, Willesden, London. N.W.10. Dated April 23rd, 1937. No. 11,704.

This is a dual control mechanism and two control members of the type consisting of a shaft slidably but non-rotatably mounted in a member rotatable, but prevented from endwise movement are directly coupled to the elevator, and are inter-connected so that the sliding movement operates the elevator. The rotatable members are also inter-connected and coupled to the ailerons so that turning movements can be controlled by either of the two shafts.

494,146. *Improvements in or relating to Actuating Systems for Controls on Aircraft.* Siemens Apparate und Maschinen Gesellschaft mit Beschrankter Haftung, Askanischer, Platz 4, Berlin, S.W.11, Germany. Convention date (Germany), Jan. 16th, 1936.

The control system has a hand control and an auxiliary power actuator, both being attached to the control to be operated, the control surface having a regulating member disposed in or connected with the transmission from the hand control to the member to be actuated. The regulating member is so adjusted that the displacing force applied by the auxiliary power is related to the manual force. The adjustment can be effected by means of the hand control member in the event of the failure of the operating medium. A further auxiliary power actuator is fitted so as to nullify the effect upon the hand control of friction landing flap actuations or the like.

494,148. *Improvements in or relating to Liquid Pressure Control Systems.* Automotive Products Co., Ltd., Brock House, Langham Street, London, W.1, and Parker, S. M., of the same address. Dated Dec. 18th, 1937. No. 2,816.

This control system is intended for the operation of controlled units on aircraft which are assisted in one direction by gravity. The pump operates a double acting slave cylinder, and the valve controlling the fluid flow limits the rate of flow of the liquid as the controlled unit moves under gravity. At the same time it allows unrestricted flow of liquid into the same end of the slave cylinder to move the controlled unit in the opposite direction, by means of a by-pass valve opened to by-pass the flow limiting valve so that in the event of an increase in the resistance to movement of the controlled unit by the resulting rise in pressure in the liquid flowing to the slave cylinder.

492,669. *Improvements relating to Means for Equalising or Balancing the Operation of Aircraft Flaps, Retractable Undercarriages, or other Adjustable Aircraft Elements.* Dowty, G. H., Arle Court, Cheltenham, Gloucestershire. Dated March 23rd, 1937. No. 8,530.

In order to ensure equality of movement of two separate components such as wing flaps or undercarriages, they are interconnected by a double acting hydraulic piston and cylinder and cross connections between the opposite sides of the pistons thereof so that fluid displaced by the movement of the piston operating with one part is accommodated by the equal movement of the piston operating with the other part. The pistons and cylinders may be arranged in tandem fashion as double acting jacks.

DE-ICING.

495,570. *Improvements connected with the Prevention of Ice Formation on the Wings and Other Parts of Aircraft.* Bullock, B. C., 28, Victoria Street, London, S.W.1. Dated April 14th, 1937, No. 10,644, and Sept. 25th, 1937, No. 26,032.

The method proposed consists of a closely woven fabric formed partly of wire and partly of fabric, secured along the leading edges of the wing or other parts of the aircraft, and to be supplied along the inner or outer side with an anti-freezing fluid so that the fluid may seep through the fabric. The warp may be of wire and the weft of yarn or vice-versa.

495,635. *Improvements Connected with the Prevention of Ice Formation on the Wings and Other Parts of Aircraft.* Bullock, B. C., 28, Victoria Street, London, S.W.1. Dated April 14th, 1937, No. 21,896; June 10th, 1937, No. 21,897; and Sept. 25th, 1937, No. 21,898.

There is secured along the leading edges of the wing or other parts a covering of a closely woven cloth consisting partly of wire and partly of yarn and an anti-freezing fluid is allowed to seep through the cloth. The cloth may be held by clamps in recesses within the leading edges of the wing and the anti-freezing fluid may be supplied to a looped portion held in the clamp, the cloth being turned back and secured along the leading edge at each side of the recess. The cloth may be in separate sections and each held in its own clamp and each supplied with anti-freezing mixture by a separate pipe.

ENGINES.

498,224. *Improvements in Elastic Mountings for Engines and the Like.* d'Aubarede, P.C.A.M., Saint Genis-Laval, Rhone, France. Convention dates (France), June 9th, 1936, and Dec. 16th, 1936.

It is proposed to insert a universal transmission joint between an engine and its propeller. The joint may be made of elastic material and the propeller shaft may be connected to the engine by an intermediate shaft. The engine is mounted on its frame through elastic joints and by a spring system.

500,247. *Improvements in and relating to the Elastic Mounting of Prime Movers.* Voight, 13, Woyrochstrasse, Berlin, W.35, Germany. Convention date (Austria), June 25th, 1937.

The motor is to be elastically mounted and a measuring device is provided which gives a continuous indication of its change of position due to deflection of the mountings. These mountings are highly elastic with wide clearances and the deflections may be used for continuously measuring the torque of the motor in flight. Further, the thrust of the airscrew may also be measured under the various conditions of flight. The readings can be shown on an instrument so that the pilot is acquainted with the work the engine and airscrew are giving.

500,252. *Improvements in Elastic Mountings for Engines Carrying Airscrew Propellers.* d'Aubarede, P.C.A.M., Saint Genis-Laval, Rhone, France. Convention date (France), June 9th, 1936

This is a flexible mounting for a V engine and airscrew, which has a flexible member near the propeller so as to form the centre of oscillation of the engine, while a second flexible member is at the opposite end of the engine, so arranged as to permit limited horizontal movements while suppressing vertical ones. The flexible member near the airscrew may have a rubber sleeve and may be designed to deal with the torque, the rear flexible member may consist of vertical leaf

springs or may be formed of rubber blocks, and the freedom may be limited by abutments.

500,538. *Improvements in Elastic Mountings for Engines Carrying Airscrew Propellers.* d'Aubarede, P.C.A.M., Saint Genis-Laval, Rhone, France. Convention date (France), June 9th, 1936.

This is an elastic mounting for a radial engine, having two unequal systems of elastic members, one forming the centre of oscillation while the other one forms the spring means. The mounting has a rigid longitudinal extension rigidly fixed to the rear of the engine, one elastic system being disposed at the extremity of the said extension beyond the corresponding end of the engine, and at a distance from the plane of the cylinders which is materially greater than the distance from the other elastic system to the said plane.

499,004. *Arrangements of Aircraft Engines and Propellers.* Armstrong-Siddeley Motors, Ltd., and Fell, L. F. R., both of Armstrong-Siddeley Works, Park Side, Coventry, and Lloyd, J., Sir Armstrong Whitworth Aircraft, Ltd., Whitley, Coventry. Dated June 24th, 1938. No. 18,750.

The engine is disposed within the wing, being of such a shape and size that this can be done without thickening the wing. Air for cooling is taken in through the leading edge of the wing and is ejected near the trailing edge, the propeller being a pusher. This rear opening for ejection is of the form of a slot situated centrally behind the propeller and approximately equal in length to the propeller diameter. The inlet is of lesser length.

495,469. *An Improved Method of and Means for Propelling Aircraft.* Prof. Dr. H. Wagner, Cunostrasse 67b, Schmargendorf, Berlin, Germany. Convention dates (Germany), Feb. 8th, 1936, and Feb. 8th, 1936.

This describes a gas turbine consisting of a compressor, a combustion chamber and a turbine, and the exhaust gases may be discharged to the rear. The output of such a turbine may be maintained at high altitudes by increasing the circumferential velocity of the turbine giving a higher compression ratio and improved efficiency. The gearbox between the turbine and the propeller is arranged with a variable gear so as to keep the propeller revolutions constant and the propeller may have a variable pitch.

493,120. *Improvements in the Suspension and Mounting of Internal Combustion Engines or Other Engine Units.* Julien, M. F. A., Avenue Theophile Gautier No. 58, Paris, France, and Paulsen, J. F., 6, rue Francois Gaillard, Viroflay, Seine et Oise, France. Convention date (France), March 28th, 1936.

This is a mounting for a radial engine with resilient supports, each support having metallic rings or tubes with rubber connecting them together by adhesion. The rings are arranged concentrically to the axis of the crankshaft passing through the C. of G. of the engine. One support is situated at the opposite end of the engine to the propeller and a second support is attached to the propeller end of the engine. These supports are preferably connected by links.

493,107. *Improvements in the Suspension and Mounting of Internal Combustion Engines or Other Engine Units.* Julien, M. F. A., Avenue Theophile Gautier No. 58, Paris, France, and Paulsen, J. F., 6, rue Francois Gaillard, Viroflay, Seine et Oise, France. Convention dates (France), March 28th, 1936, and Feb. 24th, 1937.

Engine mountings comprising resilient suspensions longitudinally arranged in groups of resilient supports on either side of the engine, each support being

formed of elastic material adhering to a part rigid with the engine and to a part rigid to the body, the surface of the adhered parts being normal to a plane which includes an axis passing through the centre of gravity of the engine and parallel to the crankshaft. The resultant of the resilient reactions passes through the centre of gravity of the engine.

492,904. *Improvements in and relating to Engine Cooling Systems for Vehicles and Aircraft.* Boulet, G., 1, rue des Erables, Plessis-Robinson (Seine), France. Convention date (France), April 2nd, 1936.

It is proposed to recuperate the heat in the cooling air of an internal combustion engine by means which includes at least one stationary set of blades through which the cooling air flows; the blades are streamlined and arranged like the blades of a low pressure steam turbine, so as to convert a part of the heat carried away into a thrust on the blades which are disposed so that this thrust is propulsive. The blades may be hollow so as to form circulating conduits for the cooling liquid of a liquid-cooled engine.

FLYING BOATS.

497,780. *Improvements in or relating to Controlling Flying Boats During Take-off, Flight and Alighting.* Waller G., 2, Wartling Road, Eastbourne, Sussex. Dated Feb. 26th, 1938. No. 6,124.

It is proposed to provide flying boats with hydrovanes and to arrange that the angle of incidence of these hydrovanes, the angle of incidence of the wings and the line of thrust of the airscrews may be simultaneously adjusted.

499,069. *Improvements in or relating to Flying Boats.* Dornier-Werke G.m.b.H. and Dr. Ing. N. C. Claude Dornier, both of Friedrichshafen, Lake Constance, Germany. Convention date (Germany), March 31st, 1937.

The proposed flying boat has a wing which, in front elevation, is shaped like a laterally extended W, the lower angles of which form buoyant supports taking the place of wing-tip floats, while the upward angle in the centre terminates in the hull. The boat may carry retractable undercarriages at the lowest points of the wing.

MISCELLANEOUS.

496,387. *Improvements in the Suspension of Vibrating Machines.* Julien M. F. A., 58, Avenue Theophile Gautier, Paris, France. Convention date (France), Sept. 19th, 1936.

The suspension has a number of link members of the same length unstressed, articulated by ball and socket or other universal joints to the body and its support and maintaining the body and support parallel or in substantially parallel relationship, and permitting combined translational movement of the body in a direction normal to its longitudinal axis and rotational movement about that axis, the said movements being opposed by resilient means.

PARACHUTES.

499,850. *Improvements in or relating to Parachutes.* Popelakova, M., Hladkor 701, Prague, XVIII, Czecho-Slovakia. Convention date (Czecho-Slovakia), April 25th, 1936.

This is an attaching device for parachutes consisting of fastening parts secured to the pack and engaging parts attached to the harness arranged so that the engaging parts are held on to the body of the parachutist at a constant distance from each other which corresponds to the distance between the fastening parts secured to the pack, whereby the fastening parts on the bag may be simultaneously connected to the engaging parts.

499,409. *Improvements in or relating to Parachutes.* Hart, R. P., 29, Southend Avenue, Darlington, Co. Durham. Dated July 29th, 1937. No. 20,950.

It is proposed to provide a parachute having a device which is automatically inflated during descent, forming a raft which is capable of floating on water. The inflatable compartment is contained in the canopy and it is inflated by the air under the parachute.

492,777. *Device for Automatically Opening Parachutes.* Clark, D. R., Main and Brampton Road, Amherst, Erie, New York, U.S.A., and Bird, W., 234, Barton Street, Buffalo, Erie, New York, U.S.A. Dated May 25th, 1937. No. 14,463.

In mechanism for opening parachutes there is incorporated dashpot mechanism having a valved piston rod, having the piston rod connected externally to the setting element and retained in an energised state at the end of its movement in one direction by the releasable locking device and connected by an intermediate member to a detent actuating member which controls displacement of the detent through eccentric action, so that on release of the setting element from its strained position it is automatically moved by the piston in its other direction and transmits movement through said actuating member, so releasing the detent.

PARACHUTES.

493,958. *Parachutes, Parachute Harness and the Release Mechanism Relating Thereto.* Taylor, E. H., Brookside, Combs, Derbyshire, nr. Stockport, Cheshire. Dated May 5th, 1937. No. 12,806.

The parachute is connected to the harness by detachable means in which the operation of connecting the two also connects the parachute release mechanism to actuating means located on the harness. The detachably connecting means proposed consist of one or more D rings associated with one of the parts and one or more snaphooks associated with the other part, either being associated with the mechanism for releasing the parachute from the pack.

494,022. *Improvements in Detachable Connectors for Parachute Harness.* Quilter, J. R., Stadium Works, Woking, Surrey. Dated April 23rd, 1937. No. 11,672.

This is a detachable connector for a parachute harness adapted to maintain the harness conveniently in position, but enabling the wearer to free himself when desired. It has two parts with a yielding engagement with each other one of the parts being secured to a lift strap and the other fastened to the wearer, the connection being firm enough to resist a moderate tension, but adapted to yield to a releasing movement of the wearer or to the greater tension exerted by the lift strap or the like when the parachute comes into operation. The connector has parallel flanges and a pin from one to the other, spring jaws engaging between the flanges. The extremities of the jaws diverging at an angle to allow them to be forced apart as the pin enters between them and the inner parts of the jaw, being shaped so as to engage around the pin at the limit of its inward or entering movement.

PILOTS AND PILOTING.

498,940. *Apparatus for Instructing Aircraft Pilots in Instrument Flying Methods.* C. Lorenz Aktiengesellschaft, Lorenzweg, 1, Berlin-Tempelhof, Germany. Convention date (Germany), Oct. 15th, 1936.

A visual representation of the landing space is provided on a reduced scale, and on this a visual representation of an aircraft is arranged to be shifted in all directions. The signals of a radio beacon are imitated and they vary with the displacement of the aeroplane.

ROTORCRAFT.

498,363. *Improvements relating to Rotors for Rotating-Wing Aircraft.* Prof. H. Focke, 30, Strassburger Strasse, Bremen, Germany. Convention date (Germany), Aug. 16th, 1937.

The blades of the rotors are mounted articulately, and each blade is fitted with projection arms with spring connections between the arms, in order that the incidence of the blade may be automatically varied as it lags or overtakes. The The arms are attached to blade spars in the manner of cranks and are preferably streamlined. There is also an opposed spring device operative on the pivot mounting of the blades which acts so as to preserve a given blade incidence.

500,192. *Improvements in or relating to Captive Flight Devices.* Chupp, C. B., 218, Jericho Road, Abington, Pennsylvania, U.S.A. Convention date (U.S.A.), Aug. 1st, 1936.

The device proposed has a body, fixed stabilising surfaces and a sustaining rotor; is in fact somewhat like a man-lifting kite sustained by a rotor. The rotor axis is constructed for automatic adjustment to different angles in the longitudinal vertical plane under the influence of varying pull of the tow rope. The angle of incidence of the rotor blades may be controlled, there is a stabilising plane in the rear, dihedral stabilising surfaces may be fitted and the rotor axis may be bodily moved.

499,073. *Improvements relating to the Control of Helicopter or Rotating Wing Aircraft.* Focke, H., 30, Strassburger Strasse, Bremen, Germany. Convention dates (Germany), Oct. 4th, 1937, and May 30th, 1938.

In rotating wing aircraft or helicopters with side-by-side rotor arrangement where elevation is effected by fore-and-aft tilting of the rotors, lateral control is effected by means producing tilting movements of the rotor axes and connected to the lateral control of the aircraft so that operation of this control causes differential forward and backward tilting of the two rotors. This arrangement may be operated by a rudder bar.

496,502. *Improvements in Helicopters.* Hammond, E. V., 88, Louisville Road, Balham, London. Dated June 23rd, 1937. No. 17,488.

The improvement described is a pitch-changing device for helicopters either free flying or anchored to the ground in a similar manner to a kite. The rotor support has a hub and a driving member for the hub mounted on said support, the hub has pivotal connections for the blades which are capable of limited rotation. They are connected to the driving member by links. Rotational movement can take place between the hub and its driving member, which relative rotational movement is utilised to effect a change in blade pitch angle.

492,816. *Improvements in and relating to Aircraft with Sustaining Rotors.* The Cierva Autogiro Co., Ltd., Bush House, Aldwych, London, W.C.2, and Bennet, J. A. J., 67, Grove Way, Esher, Surrey. Dated April 6th, 1937. No. 9,799.

A sustaining rotor for a jump take-off having an articular mounting for a rotor blade, comprising pivot means displacement about which is constituted by a leading and lagging displacement of the blade compounded with a variation of pitch angle and other pivot means permitting leading and lagging displacement of the blade independently of the displacement on the first named pivot means and stops limiting the displacements about each of the pivot means in one directing at least wherein the mentioned parts are so relatively disposed or wherein additional means are provided which are so operative that when the rotor is rotating, but not driven, the action of centrifugal force is used to lock the first named pivot means, the second pivot means being free.

492,911. *Improvements in and relating to Sustaining Rotors for Aircraft.* The Cierva Autogiro Co., Ltd., Bush House, Aldwych, London, W.C.2, and Bennet, J. A. J., 67, Grove Way, Esher, Surrey. Dated April 6th, 1937. No. 9,801.

The compound flapping pivot mechanism has two independent pivot axes together with physical constraints interconnecting the articular mechanisms of the several blades in such a way as to prevent the fundamental component of at least the non-differential flapping from taking place about one of the axes, or to prevent coning or differential flapping taking place about both axes, being inclined at different angles to the radial axes of the rotor blades so that a given angular flapping displacement is accompanied by a different change of pitch angle according as it takes place about the two axes.

SEAPLANES.

499,883. *An Improved Form of Seaplane.* Cox, H. R., 119, Cromwell Road, London, S.W.7, and Coombes, L. P., Wynchlea House, Church Avenue, Farnborough, Hampshire. Dated Aug. 3rd, 1937. No. 21,325.

It is proposed to construct a seaplane in the form of a flying wing, there being no hull, the wing being used for sustentation, accommodation of load, and support on the water. The wing is so formed as to have an extended bow, and while the section everywhere is of normal aerofoil type the underside has a planing bottom similar to that of a normal flying boat. The trailing edge of the centre section forms a flap which is so arranged that by moving it upwards a transverse step is formed on the underside of the wing.

UNDERCARRIAGES.

498,540. *Improvements relating to Aircraft Undercarriages and Wheel Brakes.* Dowty, G. H., Arle Court, Cheltenham, Gloucestershire. Dated October 13th, 1937. No. 27,869.

In this arrangement it is proposed that where a wheel and brake are mounted on an undercarriage leg and where the brake consists of a drum rotating with the wheel on an axle integral with the leg, it is proposed to use an anchorage between the non-rotating shoe and the leg, consisting of a link extending between the two. The object is to obviate the necessity of transmitting brake torque through the axle.

498,361. *Improvements in Tail Skids or Tail Wheels for Aircraft.* Saulnier, R., 5, rue de Menceau, Paris, France. Convention date (Germany), Jan. 22nd, 1937.

In the case of a skid or tail wheel made under Patent 462,963 the skid or wheel can be withdrawn into or drawn out of the inside of the body of the aircraft by varying the effective length of a mechanism which includes the shock absorber and connects a suitable point of one of the arms that bears the supporting tube of the skid with a stationary part of the aircraft.

497,559. *Knee-Shaped Spring Leg for Aircraft.* Arado Flugzeugwerke Gesellschaft mit beschraenkter Haftung, Brandenburg (Havel), Germany. Convention date (Germany), July 30th, 1937.

This knee-shaped leg is arranged so that landing and other loads are transmitted from the lower limb to the upper, which carries a spring by either hydraulic or mechanical means. The spring leg may be formed as a cylinder carrying a piston under the action of a spring, while the shocks are transmitted to the fluid through a piston in the lower limb.

500,574. *Improvements in or relating to Shock Absorber Struts for Aircraft.* Onions, J. H., 18, Telford Avenue, Leamington Spa, Warwickshire, and the Ribbesford Co., Ltd., Brock House, Langham Street, London, W.1. Dated Aug. 12th, 1937. No. 22,209.

The shock absorber has a locking valve controlling the flow of liquid into or out of the cylinder of the strut, the locking valve being automatically urged to take up a position preventing such flow of fluid, and being movable from that position only by the pressure of fluid supplied to effect a change of length in the strut. The locking valve comprises a piston normally biassed to take up a position in which it seals the cylinder of the strut, and is moved from that position by pressure fluid supplied to change the length of the strut, to connect the cylinder to a source of pressure, or an exhaust reservoir.

499,500. *Improvements relating to Locking and Operation of Retractable Parts of Aircraft.* Aircraft Components, Ltd., Arle Court, Cheltenham, Gloucestershire, and Bound, R. H., of the same address. Dated July 24th, 1937, No. 20,546, and Nov. 17th, 1937, No. 31,621.

In the case of retracting gears moving during retraction about a fixed pivot axis, the retracting jack travels in continuation of the operating stroke and in doing so operates a locking device. The travel for unlocking caused an abutment to register with a fixed guide shaped as a circular arc, which prevents locking or unlocking except before the start of or after the completion of an operating stroke.

500,477. *Improvements relating to the Control of Fluid-Operated Systems Particularly for Aircraft.* Dowty, G. H., Arle Court, Cheltenham, Gloucestershire. Dated Aug. 5th, 1937. No. 21,634.

It is proposed to add to the hydraulic control system described in Patent No. 480,674, which consists of the provision of a pressure accumulator to the pressure delivery system between the pressure source and the selector valve unit so as to receive pressure liquid against resilient resistance and thus to relieve pressure in the event of pressure delivery becoming excessive. The accumulator may contain an idle piston separating the pressure fluid from trapped air.

496,067. *Improvements in Aeroplane Landing Gear.* Robertson, J. H., 1, Albemarle Street, Piccadilly, London, W.1. Dated June 15th, 1937. No. 16,600.

The gear consists of an endless track bearing on a wheel and with tracking rollers, the track is such that it wraps round the wheel for a considerable length. Contact with the ground takes place under the wheel. A spring control may be incorporated so as to vary the disposition of the load between the wheel and the track.

496,080. *Improvements in or relating to Retractable Undercarriages for Aircraft.* Automotive Products Co., Ltd., Brock House, Langham Street, London, W.1, and Thornhill, P. W., of the same address. Dated Aug. 19th, 1937. No. 22,782.

This folding strut has two articulated parts, a lever connected to one articulated part and connected by a link to the other articulated part. Operating means act on the lever to turn it about its pivot on the strut and to cause a thrust on the link when the strut is being folded. The pivots of the lever and link on the strut parts are both spaced from the point of articulation of the strut and the link is shorter than the lever, the arrangement being such that the link approaches a position substantially at right angles to the second part of the strut as the folding operation approaches completion.

492,545. *Improvements in or relating to Aircraft Landing Gear.* The Fairey Aviation Co., Ltd., North Hyde Road, Hayes, Middlesex, and Lobelle, M. J. "Ludlow," 298, Langley Road, Langley, Bucks, and Trotter, J. C., 2, Manor Parade, Hillingdon, Middlesex. Dated June 8th, 1937. No. 15,871.

The tail wheel or tail skid is retractable from a landing position to a position nearer the tail of the aircraft, but so that it still projects so that the aircraft can take-off from a smooth surface. The tail wheel is extended automatically and concurrently with the undercarriage.

491,094. *Improvements in and relating to Jointed Mechanisms for Aircraft.* Mercier, J., 131, Boulevard de la Seine, Neuilly sur Seine, Seine, France. Dated March 4th, 1937. No. 6,492.

A jointed mechanism for aircraft for the purpose of lowering or lifting the retractable undercarriage when the aircraft is landing or starting, comprising a folding strut and jack which is mounted on the jointed mechanism and controls the deformations thereof. The strut consists of three or more pivoted elements, the jack being the sole controlling means and producing the relative displacement by direct action.

495,759. *Improvements in Operating Mechanism for Retractable Members on Board Aircraft.* Air Equipment, 64, Avenue Edouard Vaillant, Billancourt (Seine). Convention dates (France), Feb. 18th, 1935, and Aug. 12th, 1936

This is an operating mechanism for retracting members such as landing gears, turrets, etc., comprising a folding strut attached at one end to the aircraft and at the other end to the retractable member, a motor and a speed reduction device located at the articulated joint and so connected that rotation of the motor causes folding of the strut. A reversible motor may be used to fold and unfold the strut. A clutch may be interposed between the motor and the speed reduction device.

## REVIEWS.

KARL LIEBIG: "DIE PRAXIS DES METALLFLUGZEUGBAUERS," Part I, Werkstoffkunde (The Practice of Metal Aeroplane Manufacturing, Part I, Materials). Berlin, 1937. Publ. by Dr. M. Matthiesen and Co. (before by Dr. Max Gehlen). 108 pp., 14 figs. Price R.M. 1.80.

This little instruction manual is compiled for use of soldiers of the Air Force and of apprentices. It gives a fairly complete and modern survey of materials used in the manufacture of aeroplanes (including non-metallic materials) and includes procedures like heat treatment, case hardening, tempering and protection against corrosion. Plastics, rubber, synthetic rubber and safety glass are also referred to.

A. FELGIEBEL: "BENZINMOTOREN FUER FLUGMODELLE UND IHR SELBSTBAU" (Petrol Engines for Flying Models and their Home Construction). Berlin, 1939. Publ. by C. J. E. Volckmann Nachf. E. Wette. 143 pp., 179 figs., 7 tables with detail drawings.

Flying models driven by small single-cylinder petrol engines have become fashionable lately and, therefore, a book dealing with the construction of these engines should fill a gap. This German treatise is obviously written by an engineer who knows his job perfectly. The book is more than a mere description of types marketed in Germany and in U.S.A. It is a comprehensive and instructive study of the peculiarities of tiny petrol engines, their installation and their service. Further, the author describes the construction of a simple two-stroke model engine (in two sizes, 7.6 cm.$^3$ and 14.3 cm.$^3$) of his own design complete with good detail workshop drawings and with many hints for the home manufacture, the casting included. Model enthusiasts should welcome this book as a valuable contribution for home constructors.

THE DRAMA OF WEATHER. By Sir Napier Shaw. Published by The Cambridge University Press. Price 10/6.

This is the second edition of this book. Certain alterations and additions to the text have been made in view of certain advancements which have been made in the science of meteorology, but, mainly, the book remains in its original form.

Weather is, of course, one of the principal items of interest in this Country, which probably has more variations of weather during the year than almost any other part of the world; it is a universal subject of conversation and the question whether it is going to rain to-morrow is of interest to everybody, especially at holiday time. But very few, even among the more intellectual portions of the community, understand what is known about the subject, or even of principles which the Meteorological Office uses in connection with the making of a forecast.

This book represents the best attempt so far made to bring the subject of meteorology within the knowledge of the ordinary citizen. It is not always easy reading but the author has successfully avoided all mathematics, except in one instance when he gives, with an apology, a differential equation. For those who wish to know more about the constant changes that are taking place in the sky, the witnesses of the turmoil of the atmosphere, to understand why clouds are formed, and why they take the many shapes that are so well known to us, to follow the phenomena of rain, hail or snow, with a knowledge of the reasons for them, this book can be thoroughly recommended.

H. WENKE: "FLUGLEISTUNGSERMITTLUNG" (Aeroplane Performance Testing). Vol. 8 of "Praktische Theorie in der Flugtechnik." Berlin, 1938. Published by Dr. M. Matthiesen & Co. (before by Dr. Max Gehlen). 112 pp., 51 figs. and four form sheets. Price RM. 4.-.

Methods for conducting performance tests with aeroplanes have nowadays become fairly elaborate and intricate, and the requirements as to accuracy have become higher. The author of this booklet has compiled the procedures practised in Germany (especially those used by the Junkers works) as a short working manual for the test engineer. Due care is taken to point out errors and inaccuracies which may affect the results. Conversion formulæ for the reduction of observed values to the standard atmosphere are included as well as practical form sheets for the use of test observers. The measurement of starting and landing performance for land- and seaplanes, the determination of speeds, climbs and ceilings, the measurement of petrol consumptions and of the flying range, of excess engine power, of carbon-monoxide content in cockpits and cabins are thoroughly dealt with and illustrated by practical examples. As far as possible the author has endeavoured to describe competitive methods for the same test.

As a short manual for test observers the booklet may be recommended.

AERO ENGINES, VOL. II. By Various Authors. Published by Charles Griffen & Co. Ltd. Price 18/-.

This book deals in detail with the following engines: the Armstrong-Siddeley Cheetah, the Bristol Pegasus, the De Havilland Gipsy Major, the Napier Dagger, and the Rolls Royce Kestrel. Each engine is described by a separate author, each of them being an expert on the type he deals with.

In each case the information given is extensive and authoritative. It starts with a general description, a description in detail of carburettors, lubricating system, magnetos, auxiliary drives, and full details are given for overhauls, complete and partial, routine maintenance, troubles and remedies, and how to handle the engine during starting and running. It is illustrated excellently throughout by diagrams and photographs.

It is, perhaps, one of the characteristics of the present engineering era that the output of text books on the various engineering matters has increased enormously. This is all to the good, and the newcomer is now enabled to obtain information by reading a book which previously he would have had to absorb by practical experience in a much slower manner. Although book reading can never completely take the place of practical experience, yet it must save much time by telling the novice what difficulties to look for, how to get over them, and the principles involved.

It is on these grounds that a book of this type is to be welcomed. For the learner it would be invaluable while for the experienced worker it contains much information which is necessarily useful especially if he has to deal with an engine type previously unfamiliar.

LIGHTER THAN AIR.

By Stephen Wilkinson, A.F.C. Published by Arthur H. Stockwell, Ltd. Price 6/-.

This book, which has a short foreword by Major-General Ashmore, is a chatty description of the author's experiences during the late European War. An architect by profession, the author was in India when the war broke out and he returned to England to join up. After several experiences in which those in authority tried to fit him into places for which he was not suitable, he became a balloonist.

In the late war experience with balloons was considered essential for those concerned with lighter-than-air aircraft. A dirigible might conceivably have engine trouble so seriously as to make a landing without power essential, while

kite balloons might break away from their moorings, and have to be landed across country. It was considered essential that those engaged in these activities should know what to do when a forced landing became necessary and there was no better way of teaching than to put them through a full balloon course.

Generally, the book is a brightly written account of an aspect of the late war which is commonly forgotten, but which might quite easily become necessary again. Such reminiscences have a value as a record of experience, and also as a record of adventure bravely undertaken.

AIRCRAFT DESIGN.

By C. H. Latimer Needham, M.Sc., F.R.Ae.S. Published by Chapman and Hall, Ltd. Price 13/6.

This is the first volume of a series dealing with the subject indicated by the title, and it discusses the subject of aerodynamics. From the general point of view the treatment is comprehensive. The book starts with a certain amount of theoretical work, and goes on to deal with the usual subjects of applied aerodynamics, the later chapters including such matters as stability control, slots, loads in manœuvres, airscrew performance, etc.

The work generally is not written from an advanced standpoint. Many of the usual formulæ are given without proof, and there is no general bibliography, though a few references are given in the text to official and other publications. In a work of this type a bibliography is of special importance, so that those who wish to know more about the subjects discussed shall know where to look.

It is uncertain for what class of reader this book is intended. It is not sufficiently advanced for students reading for a B.Sc. or an A.F.R.Ae.S., and it is presumed that most of the aircraft designers and design draughtsmen will require more theoretical work in any book on this subject that they may want to use. But, on the other hand, there may be some designers belonging to small firms who may find this book useful. Unfortunately the book shows signs of being hurriedly written. An example showing this haste is provided by the definition of axes in Fig. 57 and the different names given to these axes on page 102.

*The 639th Lecture read before the Royal Aeronautical Society since its foundation on January 12th, 1866.*

## PROCEEDINGS.

At a meeting of the Royal Aeronautical Society, held in the lecture hall of the Institution of Mechanical Engineers, Storey's Gate, Westminster, London, S.W.1, on Thursday, December 1st, 1938, a paper on "The Flying Controls of the Aeroplane," by Professor G. T. R. Hill, M.C., M.Sc., M.I.Mech.E., F.R.Ae.S., was presented and discussed.

In the chair, Dr. H. Roxbee Cox (Fellow).

THE CHAIRMAN: Science to-day was fortunate in having a range of very eminent "Hills," among them the lecturer. Those concerned with aeronautics distinguished him from others of his name by thinking of him as the "tailless Hill." That epithet, of course, implied no peculiarity on the part of his namesakes, but was a tribute to a great achievement of his own, for between 1925 and 1934 he had produced several extremely interesting aeroplanes of the tailless kind which represented very great contributions to our knowledge. They were ingenious in many respects, apart from being tailless, and some of them were fitted with tricycle undercarriages, apparently before their time. Those aeroplanes had presented some very difficult control problems, so that Professor Hill's interest in control dated back many years. As Chairman of the Stability and Control Sub-Committee of the Aeronautical Research Committee, he was ideally situated to review problems of control.

Professor HILL: The paper must not be considered as being a report of the Stability and Control Sub-Committee of the Aeronautical Research Committee. It embodied only his personal views, many of which would probably be regarded as heretical, in which case he hoped the members would say so in the course of the discussion.

## THE FLYING CONTROLS OF THE AEROPLANE.

By Professor G. T. R. HILL, M.C., M.Sc, M.I.Mech.E., F.R.Ae.S.

### PART I.

### GENERAL STUDY OF THE PROBLEM OF CONTROL.

1. Introduction.
2. Relation of Control to Stability.
3. Experiments on Harmony of Controls.
4. Pilots' Opinions on Control and Stability.
5. Quantitative Measurement of Control.
6. Early Attempts to Measure Control.
7. Quantitative Specification of Control.
8. Definition of "Pleasant" Control.
9. Position, Velocity and Acceleration Controls.
10. Lag.

### PART II.

### MAINTENANCE OF TRIM.

1. Theory and Practice.
2. Change of Trim with Throttle Opening.

3. Change of Trim with Flap Operation.
4. Ground Influence on Trim.

PART III.

SOME RECENT DEVELOPMENTS.

1. An Improved Method of Balancing Control Surfaces.
2. A Quickly Operable Flap.
3. Aileron Control Replacement.
4. Two-Control Systems.
5. Flying Models.

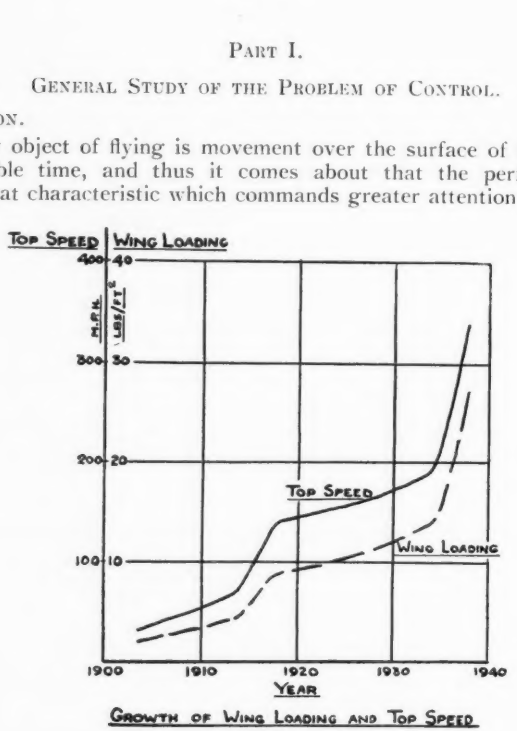
SUMMARY.

## PART I.

### GENERAL STUDY OF THE PROBLEM OF CONTROL.

1. INTRODUCTION.

The primary object of flying is movement over the surface of the earth in the shortest possible time, and thus it comes about that the performance of an aeroplane is that characteristic which commands greater attention than all others.




GROWTH OF WING LOADING AND TOP SPEED

FIG. 1.

Human life is still of some account, and the world demands, in addition to high performance, a measure of safety in flight dependent upon the nature of the duty involved; to take extreme cases, it is not considered unreasonable that an aeroplane built to attain a record speed should be less safe to fly than one built for the transport of passengers. Many factors must be taken into account in assessing safety, and one of the most important forms the subject of this paper, the flying controls of the aeroplane.

In addition to its effect on safety, control has a close relation to performance; this relation is not a direct one, and is easily lost sight of in the search for high speed. Fig. 1 shows the steady increase of wing loading which has taken place

since the first flight made by the Wright brothers in 1903, and on the same diagram is an indication of the rise in speed. The general trend has been illustrated by the selection of a certain number of successful types noted for good performance in their day. High speed is thus closely bound up with high wing loading, and the use of high wing loading has always been, and will be for some years yet, dependent on the degree of safety which can be achieved during the take-off and landing. So we are led back again to our consideration of control through its influence on performance by a restriction on wing loading in the interests of safety.

If we are now agreed that improved control will lead to higher speed as well as greater safety, we may turn our thoughts towards ways and means of improvement.

We are immediately confronted with the position that, in trying to make our improvements, we have nothing definite to aim at; nobody has yet succeeded in defining, in any detail, the target.

Let us consider first what sort of target we are aiming at. We want the best possible control. Now it cannot seriously be argued that there is one best combination of qualities; many different combinations will be acceptable as giving highly satisfactory results, and the scoring on our target will be entirely "non-standard"; the bull's-eye will cover a great part of the whole area, and an aeroplane whose qualities can be plotted anywhere on this area will be regarded as good. Aeroplanes which are flyable, but about which complaint is made, can be considered as lying outside the bull's-eye, but can still be plotted on the outer part of the target; while dangerous aeroplanes, fortunately seldom met with now, can be regarded as off the target altogether.

Any definition of ideal qualities, therefore, cannot specify a single combination, but rather it must lay down limits within which behaviour will be satisfactory and outside which first an element of discomfort and then an element of danger is encountered.

This then is the nature of the problem before us, and the reason why, in my opinion, it is worthy of study. Now it will be known to most of you that the Stability and Control Sub-Committee of the Aeronautical Research Committee are engaged in work which they hope will produce results useful to designers when they have before them problems, particularly in control, for solution. The fact that I am at the moment chairman of that sub-committee was no doubt in the minds of those members of the Council who suggested that I should appear before you to-night, and it is a great privilege to be afforded this opportunity of telling you something of the work on which the sub-committee is engaged. At the same time you will understand that many of the opinions I put forward and the speculations I hazard are entirely my own, and this paper is in no sense a report expressing the official view of the A.R.C. Nevertheless, I must take this opportunity of tendering my thanks to the A.R.C., and to the Air Ministry, for allowing me to make use of information which is not yet published.

Coming now to the form of the paper itself, Part I may be said to deal with the academic aspect of control problems, the examination of the underlying causes of the behaviour of the aeroplane when manœuvring, and a discussion of the possibility of setting the whole subject on a firmer theoretical foundation.

Parts II and III describe recent experimental work which is helping to solve our immediate day to day difficulties which naturally arise when we build faster and larger aeroplanes. I have made no attempt to cover the whole of the field, but have chosen a few important and interesting problems, and have discussed the aerodynamic questions which are involved.

## 2. Relation of Control to Stability.

When a pilot judges the controls of his aeroplane, he carries out some manœuvre such as a turn, and studies the forces and movements he must make

with hands and feet, and the variation of force and movement as he carries the manœuvre right through.

It is quite clear that the control movements the pilot has to make depend to a very large extent on the degree of stability of the aeroplane; for instance, an aeroplane which is slightly unstable longitudinally can be landed with practically no movement of the stick, that is, it will flatten itself out from the glide, and my personal view is that this kind of aeroplane is particularly easy to land. However, the main point is that a study of control without reference to stability is quite meaningless. Jones in his contribution to Durand's Aerodynamic Theory, the Dynamics of the Aeroplane, has dealt with this subject at length, and I do not propose to do more than draw attention to its particular application at and near the stall, and when spinning.

During normal flight, we seldom find aeroplanes which are excessively stable or unstable, but when we come to the stall, and to the spin, we do find both conditions in practice. Violent instability in roll is frequently present at high angles of incidence near the stall, and great stability about all axes is sometimes found in a spin. In both cases, the controls are quite inadequate to permit the pilot to impose his will upon the aeroplane.

Modern practice tends towards providing, if possible, a small or moderate degree of stability in normal flight, according to type, and seeks the avoidance of gross instability at the stall, coupled with some kind of warning of the approach of the stall.

Much experimentation is being carried on in this country with the object of finding out what kinds of wing shapes are well behaved at high angles of incidence, and how such features as, for instance, engine nacelles promote premature stalling. The progress of this work lies somewhat outside the scope of this paper, but this reference to it explains the absence of an extensive discussion of stalling as it affects control. Control at the stall is still a long way from the ideal, but even if enormous improvements were made, the whole result would still be far from satisfactory if the aeroplane itself were violently unstable; it is therefore to the improvement in stability at and near the stall that most attention is now being directed in this country.

We can support this view by yet another line of argument. The weights and speeds of all service types are steadily increasing, and it seems probable that in the near future the service pilot will not have sufficient physical strength to recover from a spin, should he fall into one whilst manœuvring, or through instrument failure when flying in clouds. If this proves to be the case, it becomes more than ever important to ensure that each type has no inherent tendency to spin, in other words, that the stability at the stall is satisfactory.

### 3. Experiments on Harmony of Controls.

In the course of discussion on control measurement by the A.R.C. during the last year or two, many doubts were cast upon the hope that any result of value could emerge. Was not the whole practice of defining "ideal control" or "ideal stability" too vague, incapable by nature of crystallisation, too much a matter of personal predilections, in fact, as one member of the sub-committee well put it—"not quite aerodynamics"?

In 1936 an investigation had been made at the R.A.E. with the object of finding what measure of agreement existed among pilots as to the meaning of the expression "harmony of controls." The investigation was made on a ground test rig, and each pilot had to adjust the relative stiffnesses (*i.e.*, increases of force per inch displacement) of the three controls to the condition that he felt to be the most desirable; in spite of the fact that the pilot had to imagine he was flying, it appeared possible to draw some broad conclusions, and my own feeling is that if the relative stiffnesses were set according to the average opinion, very few pilots would class that condition as bad; some support for this view may

be found in the almost universal popularity of some types of aeroplane from the point of view of flying qualities.

Upholders of individuality will see in this trend of thought a threat to that variety which gives such interest to life, but from the Service point of view, a standardised " feel " of the controls on all types, both large and small, would be an inestimable advantage in the rapid training of large numbers of new pilots.

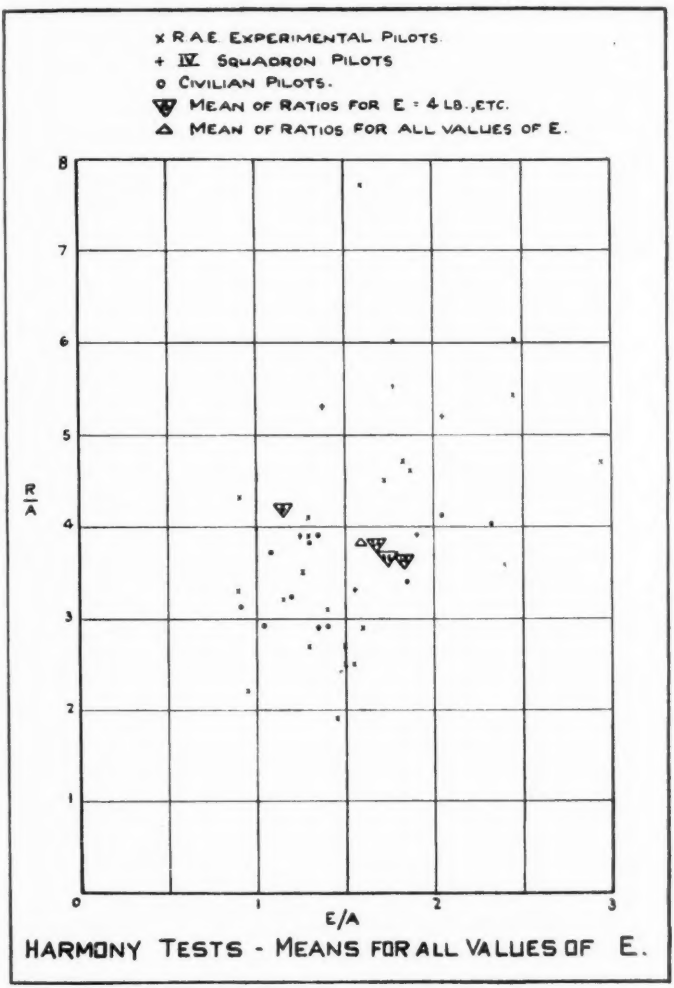



FIG. 2.

The next step is to introduce a greater degree of reality into the experiment made at the R.A.E. on the ground rig, and this is now being prepared. An aeroplane is being fitted with controls whose gear ratios and balances can be altered in the air by the pilot, who will adjust them to give him what he considers the optimum " feel." The settings arrived at by a number of pilots will

then be compared, and the hope is that the measure of agreement reached will enable a range of values to be given in which control is " good." The tests will be extended to cover different C.G. position, *i.e.*, different degrees of longitudinal stability, and different values of both dihedral angle and fin area, giving different degrees of lateral stability. We ought then to measure what we have achieved, and thought is now being given to this problem of exactly what we ought to measure, and how we ought to state our results.

4. Pilots' Opinions on Control and Stability.

The variation shown between different pilots' conceptions of harmony of controls, as determined from the ground test, was a clear warning of the danger of asking one person, or a small group, to attempt to establish even qualitative standards of ideal control or ideal stability. The sub-committee therefore drew up a questionnaire, and this was circulated to a large number of pilots through such bodies as the S.B.A.C. and Imperial Airways, as well as to the pilots at the Air Ministry Experimental Establishments, and the Central Flying School.

Pilots were asked to consider the bearings of their answers on three classes of aeroplanes:—

(i) Small type (single-seater fighter).
(ii) Medium type (two-seater fighter and bomber).
(iii) Large multi-engined type (bomber or civil transport).

Where size affects the answer to any question, details have been given; in other cases, all types have been bracketed together, and one answer given.

We now come to the résumé of the pilots' replies to the questions asked under seven main headings, with some comments where difficulties of interpretation arise.

1. *Control Force Variation.*

(*a*) *With Speed.*—It is practically unanimously agreed that there should be a slight increase with speed.

(*b*) *With Aeroplane Size.*—Opinion is about equally divided on this point, one party holding that there should be a slight increase with size, and the others desiring no increase.

(*c*) *With Displacement.*—While the majority wish for a small progressive increase, there is a large minority who state that there should be no increase.

[*Note.*—It is not really clear what is meant by the statement that control force should not increase with displacement. A control with no force under any conditions would of course comply with this requirement, but what is more probably meant is a control on which the force increases steadily to some small value at a small displacement, and after that remains constant to the full displacement. This is one example of the somewhat loose way in which the qualities and functions of controls are so often described, and this lack of true precision adds greatly to the difficulty of interpreting what is really in the pilot's mind.]

2. *Stability with Controls Free.*

It is unanimously agreed that it is desirable that an aeroplane should be capable of flying without the pilot's help. This quality is more important on large aeroplanes. Some pilots regard stability in roll as the most important, and others as the least important.

Some pilots are ready to accept neutral stability on small fighters, particularly if thereby they enjoy the highest degree of manœuvrability. Again it is mentioned that instability on the climb is also acceptable if this leads to the avoidance of excessive stability under other conditions.

It is pointed out that if a wing drops in a bump, it is desirable for the aeroplane to recover to a level keel without yawing off its course.

3. *Steadiness.*

If the stability is sufficient to allow the aeroplane to fly through moderate bumps alone, and the control is up to the standards described under headings 1 and 4, then it is unanimously agreed that the desired degree of steadiness will have been achieved.

4. *Stability of Controlled Motion.*

It is agreed that lag should be avoided. A number of pilots have suggested that lag coupled with light controls is particularly bad, and lack of harmony among the three controls is liable to cause over-controlling.

[*Note.*—See §10.]

5. *Longitudinal Trim Changes*

(*a*) *With Throttle.*—It is agreed that there should be none.

(*b*) *With High Lift Flap Operation.*—It is agreed that there should be none, or alternatively as a slight variation from this that the aeroplane trimmed to glide at a suitable approach speed flaps up would trim at a suitably lower approach speed when the flaps were lowered.

[*Note.*—There is still a crying need for exact definition of the words "no change of trim." If a stable aeroplane trims at the same air speed with engine on and off, it will drop its nose when the engine is shut off, and will usually drop it much farther than is appropriate for its steady glide. Even if it trims at a much slower speed on the glide than with engine on, it may still drop its nose initially when the engine is shut off. Confusion still exists between initial behaviour and final behaviour when defining trim. See also Part II, §§2 and 3.]

(*c*) *With Proximity of Ground.*—It is very desirable that there should be no change of trim, due to ground interference, which makes it difficult to get the tail down for landing.

[*Note.*—See Part II, §4.]

6. *Response to Ailerons and Rudder.*

Opinion is about equally divided as to which is the more important control; many pilots consider them of equal importance, and in the newer types there is a tendency to regard the ailerons as the primary control.

It is agreed that operation of the ailerons should produce no yaw.

7. *Landing.*

Flaps are unanimously agreed as necessary for flat gliding types, *i.e.*, all new types. A quickly operable flap (in its drag range) is enthusiastically commended by all pilots who have tried it, but no change in trim is demanded as essential. A gate to limit the travel to the high lift range is recommended. [See Part III, §2, for further description.]

Pilots who have not tried the rapidly adjustable flap like to set the slowly adjustable flap before the glide, and alter gliding angle with the throttle.

A body of pilots recommended that the ground angle should be less than the stalling angle, and that the elevator control should not be sufficiently powerful to pull the aeroplane up to stalling angle during landing. This, it is felt, will minimise the danger of stalling after a bad bounce.

Against this, the view is expressed that the elevator control should be more than that required for landing. These two suggestions are not necessarily completely contradictory.

5. Quantitative Measurement of Control.

The foregoing statement of flying qualities has been expressed in everyday language, with as much precision as is justified by information existing in this

country. It has for many years been my hope that some quantitative framework could be set up, so that statements such as " there shall be no lag " could be replaced by some such definition as " the angular displacement shall not lag more than 1/10th of a second behind that arising from uniform angular velocity during the first second."

As previously stated, the whole difficulty of the problem is not that we cannot make measurements, but is in deciding exactly what is to be measured, and how to transform the measurements made into something which is simple enough for comparative purposes. Stevens discussed this problem in his paper before the Society in 1930.

There is, of course, the scheme of tests for behaviour at slow speeds which is laid down in A.D.M. 293, and experience with a great number of types undergoing these tests at Martlesham Heath has proved their value. We have, however, no comparable scheme for normal flight, and the report on each type undergoing the tests is still for the most part confined to a description of the behaviour in words instead of by figures.

### 6. Early Attempts to Measure Control.

More than 20 years ago, I was carrying out some tests at the R.A.E. of the lateral control obtainable with various types of aileron on an R.E. 8, and other similar types of aeroplane. We had then a very crude type of measuring apparatus consisting of a sight line fixed transversely across the centre section of the aeroplane, at an angle of 45°; as each aeroplane was a two-seater, it was possible for an observer in the back seat to measure with a stop watch the time taken to bank through 45°, *i.e.*, until the sight-line was parallel to the horizon. This test was carried out at a series of speeds, but since some of the times to be measured were little more than one second, the accuracy of timing with a stop watch was low. In spite of this, a quantitative comparison was actually made, and these are the first full-scale tests on control with an answer in the form of a series of curves of which I am aware.

The shortcomings of the measuring apparatus were only too apparent at the time, and in addition it was unsuitable for use in the type where the highest quality of control was needed—the single-seater fighter.

This led to the development of the photographic method in which one aeroplane carrying a cine-camera pointing backwards and upwards over the tail flew along in a straight line, and the aeroplane whose control was to be measured flew up behind and performed its manœuvre, which was recorded in the film. The analysis of the pictorial record was performed graphically, and results of much greater precision were obtained. The missing link was the absence of any record of the control movements of the manœuvring aeroplane, so the experiments were confined to manœuvres performed as quickly as the pilot could carry them through.

Owing to difficulties met with in these experiments of co-ordinating the operations on the two aeroplanes, instruments to give continuous photographic records of rates of turn about the three axes were produced at the R.A.E. and were used in the study of control at and near the stall, a branch of the subject which was occupying a great deal of attention at the time when auto slots were being introduced; and similar apparatus has been developed in other countries.

### 7. Quantitative Specification of Control.

It is from the United States that the first real quantitative specifications of control and stability appear to have come. Professor E. P. Warner devised what seems to us an elaborate scheme for application to a large multi-engined transport type; the actual values of times, angles, etc., which he laid down were, in his own words, " shots in the dark," but his boldness appears to have been justified in practice, since his specifications are finding increasing application with but minor modifications in the numerical values initially chosen. Professor Warner tells me that, for reasons beyond his control, he was unable to publish his

proposals in full as he had intended, but a summary of them was given by Millikan in the " Journal of Aeronautical Sciences " of December, 1936.

8. Definition of " Pleasant " Control.

While the difficulties of laying down a quantitative specification for a large aeroplane are great, they are nothing like so great as for a small type, where the pilot demands that his craft be really pleasant to handle; there is satisfaction rather than pleasure to be found in handling the large type, and pleasure is a notoriously troublesome activity of the human mind to tie down to rules.

This is where we reach the stage where things are " not quite aerodynamics," and the psychologist must be called in to help, but I make no apology for not calling a halt. If the pilot finds his controls pleasant to handle, he learns more quickly because the process of learning is enjoyable, he gains confidence rapidly, and he and his machine become a more efficient unit of transportation, and, we must add in these days, of warfare. If, therefore, it is found possible to establish certain numerical standards, which if complied with represent a pleasant feel on the controls, then in my opinion it will do much to ease the task of the designer, who will have something quite definite to go on when he is forecasting the control qualities of his new design from a consideration of the sizes and proportions of his control surfaces.

To attempt to explain why a control feels " pleasant " is a far from straightforward matter; for in even the simplest manœuvre, say the flattening out of the flight path for landing, one must take into account the force on the stick and its displacement, the attitude and speed of the aeroplane, its height above the ground, and the variation of all these factors with time. What is the ideal way in which these factors should change as the landing is made?

The following speculations are submitted for discussion in the hope that they may ultimately form the basis for an analysis of the problem which is so baffling in its complexity.

9. Position, Velocity and Acceleration Controls.

Any control may be one of three distinct kinds, a control of position, of velocity, or of acceleration. Examples of these three types of control are first, a gun held to the shoulder; the hands provide a direct control over angular position; secondly, a motor car steering wheel, where the deflection of the wheel corresponds to a proportionate angular velocity, *i.e.*, rate of turn, of the car; and lastly, a motor car brake, which is a direct control of acceleration, in the negative sense.

Each type of control is perfectly satisfactory, and it is not obvious that any one type is better, or more easily worked, than any other. What I do suggest, however, is that some ease of operation is lost directly a control begins to possess a mixed function; that is to say, if at one period after it is operated it controls, let us say, acceleration, and then gradually changes into a velocity control. An example of this type is the motor car accelerator; if it is depressed to a certain position and held there, it first produces an acceleration depending on its position, and ultimately, after a period of time, it determines the speed of the car. An example of greater complexity still is provided by the aeroplane elevator control; if the stick is suddenly moved through a small distance, it controls first the angular acceleration, then very rapidly it changes its function and governs the angular velocity, and ultimately it determines the attitude and forward speed of the aeroplane. The aeroplane throttle control, to take another example, first gives a forward acceleration, and ultimately governs rate of climb. It is the changing function of the control that troubles the learner and it takes him time to adapt himself to the change-over; normally the man in charge of the control is not interested in all this; all he is concerned with, usually, is the integrated result; that is, he wants to have his machine in a certain position at a certain time.

It may be argued that it is not worth while going into the matter along these lines, as nothing can be done in practice to prevent the interchange between velocity and acceleration controls, even if it is proved that this interchange does give rise to difficulties in control. On the other hand, further light may be thrown on the subject of lag in controls, a vice which is universally condemned. This is dealt with more fully in the following section. Again, we may be able to understand more clearly what a pilot means when he says he likes an aileron control which makes the aeroplane feel as if it were " geared to the stick." This expressive phrase is often used, and at first sight it looks as if it described what I have labelled as a " position control," but it is difficult to believe that it is really so. The phrase usually crops up in the description of the controls of a small type which can be banked very rapidly, and in which the time taken for the pilot to move his controls over is a large fraction of the total time taken by the manœuvre. On the other hand, it may be that the absence of any appreciable lag in the control is what really produces the pleasant feel.

Whatever may be the explanation, it seems to me that there is a possibility of gaining a fuller understanding of the problem by an attempt along lines such as those I have suggested to break down its complexity through an understanding of the interaction of the many factors involved.

### 10. Lag.

The last of the control problems which seems to fall naturally into this part of the paper is the problem of the lag between the application of the control and the response of the aeroplane.

This defect may arise in at least two distinct ways. On the one hand large inertia may delay the building up of velocity as rapidly as the pilot feels it should, *i.e.*, he feels he ought to have a purely velocity control, and is in fact suffering from a weak initial acceleration control which persists too long. On the other hand, there may be a failure in the building up of the air flow to the new pattern, and cases of this trouble have occurred during the development of a type of lateral control operated by a spoiler on the upper surface of a wing, a point which is referred to again in Part III, §3.

This observed lag depends upon the estimation of very small time intervals, and some experimenters, notably in America, believe that anything greater than 1/10th of a second is unacceptable on an aeroplane which is required to have a pleasant feel.

Lag in a control is probably the most important cause of over-controlling, a matter referred to in §4, and once an oscillation is set up, it is a common occurrence for the operation of the control to force the oscillation to increasing amplitudes owing to the phase difference produced by the lag. This difficulty is not confined to rapid oscillations, and lags measured in fractions of a second, but may occur, for instance, when steering a ship, with a long period and a lag of several seconds.

## Part II.

## Maintenance of Trim.

### 1. Theory and Practice.

During the foregoing discussion of the feel of controls when manœuvring, and the manner in which the control forces change with time, we have made the tacit assumption that we are able to start with zero force in steady flight, in other words, from a condition of trim.

Some opinions relating to trim requirements are also to be found in one section of the résumé of pilots' opinions on control, to be found in Part I, §4, and we must examine this problem more fully.

We are fortunate in finding that we stand on a firm foundation of theory well linked to practice. I suggest that one reason for this firm foundation is that we

can easily make measurements, both in flight and on models, as we do not have to rely solely on pilots' opinions.

During the war great attention was paid to stability problems, particularly at the R.A.E., to the neglect of the equally important desideratum of avoiding violent changes of trim, both longitudinal and lateral, with changes in throttle. Elaborate calculations used to be made to secure lateral stability in certain designs, but in flight they exhibited a strong turning tendency due to the rotating slipstream striking on one side of the fin; if the pilot took his feet off the rudder bar, they would swing violently to disaster unless checked again by the pilot, and it was little comfort to him to know that, from the mathematical point of view, his aeroplane was quite stable.

This rather distressing example of theory and practice getting out of step has now faded far into the past, but is worth recalling as a warning against any programme which fails to link theory with practice as closely as it is possible to do.

Gradually devices such as adjustable tails and fins, springs in the control system, and, more recently, adjustable trimming tabs, became universal, so that trim can normally be secured on modern types without difficulty. What is difficult, however, is the avoidance of large changes of trim with throttle opening, and with flap operation. Even with the modest engine powers of 20 years ago, many types suffered from large changes of trim with throttle opening, and a vast number of pilots must have crashed when attempting to land, and deciding to go round again, opened up their engines, and stalled as the result of a large nose-up pitching moment being generated by the slipstream on the tail which was set for the glide.

Nowadays the use of much higher engine powers, and high lift flaps accentuate the difficulty, though of course the higher speeds associated with higher wing loadings bring down the slipstream speeds for a given horse-power.

### 2. Change of Trim with Throttle Opening

The basic idea underlying the avoidance of change in longitudinal trim is quite simple. Taking first changes with throttle, the propeller thrust couple round the

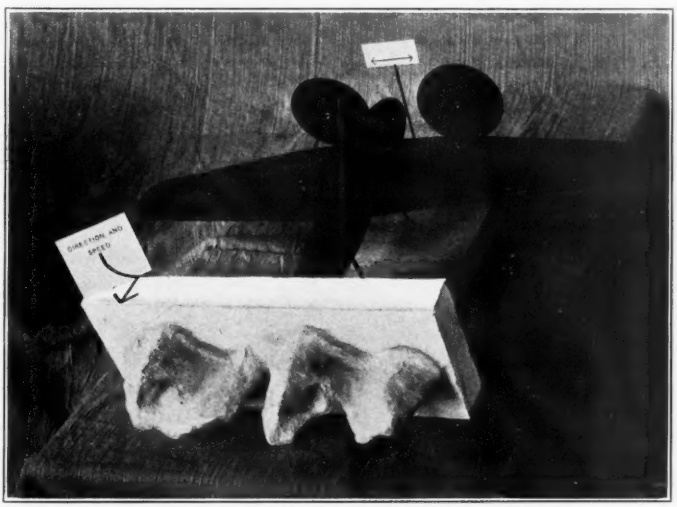



Fig. 3.

centre of gravity must balance the aerodynamic couple due to the slipstream on wings, body and tailplane; the tailplane is the source of most of the trouble, since not only the airspeed but also the downwash on the tail is increased with throttle opening.

A considerable body of information has been accumulated during the course of years on the single-engined tractor types, but with the advent of the modern multi-engined layout, unsuspected difficulties not only of trim but also of longitudinal stability were encountered by nearly all designers of these types. Some interesting model work is now in progress at the N.P.L., during the course of which the slipstream on a typical twin-engined tractor monoplane has been mapped out. In the single-engined type, the slipstream remains, if not circular, at any rate about as high as it is wide, but with two engines, the slipstreams become greatly flattened as they pass over the wing, and this distortion of slipstream shape obviously makes it very difficult to calculate what is happening to it. The actual shape which it assumes, with a flat bottom, results in tailplane lifts which depend critically on the exact vertical position of the tailplane, and any generalisation from these tests becomes very difficult. They do show, however, that we must expect designs which are much the same in a general way to behave, longitudinally, very differently in practice; and we can see now why some designers seem to have had bad luck with their designs for no obvious reason, while others, with little difference, have escaped trouble.

### 3. Change of Trim with Flap Operation.

Coming now to the changes of trim with flap operation, we have two large pitching effects produced, which fortunately oppose each other, so that it is not impossible to achieve a zero change in trim, as asked for by pilots, see Part I, §4. When the flaps are lowered, the centre of pressure on the wings moves backwards, giving a nose down moment; on account of the additional lift there is an increase in downwash, which causes a down load on the tailplane, and a nose up pitching moment on the whole aeroplane. If these two moments can be made to balance, then we have the condition of no change of trim. Some pilots favour a somewhat slower trimming speed with flaps down (see Part I, §4), and a slight preponderance of the pitching moment arising from the tail will secure this.

Although no change of trim with flap operation may have been secured on the glide, what happens if the engine or engines are suddenly opened up with the flap still down? The slipstream is in some cases deflected well downwards by the flap, and striking on the top of the tailplane produces a large and uncontrollable nose up pitching moment. This kind of trouble can be avoided by the use of a quickly operable flap, and a discussion of this device appears in Part III, §2.

### 4. Ground Influence on Trim.

The increasing use of the monoplane has brought with it another problem that has given rise to trouble in certain designs. Difficulty in flattening out to land has been encountered with some types, even though it was easy to stall them when flying well clear of the ground, and reference to this difficulty was made in the pilots' replies to the questionnaire.

The reason for this is, of course, that the presence of the ground flattens out the downwash behind the wing, and the nearer the wing approaches the ground, the greater this effect becomes. It is quite obvious that the monoplane wing is commonly much nearer the ground than the average of the two wings of the biplane, and on some monoplanes, it has been found from wind tunnel tests that up to 10° and even 20° more negative elevator angle is required to trim at a high angle of incidence when near the ground as compared with the angle required to trim at the same incidence when high up.

Theoretical work on this subject has been done recently in Japan, by Tani and others, and a fair but not wholly satisfactory measure of agreement has been found between theory and model experiment.

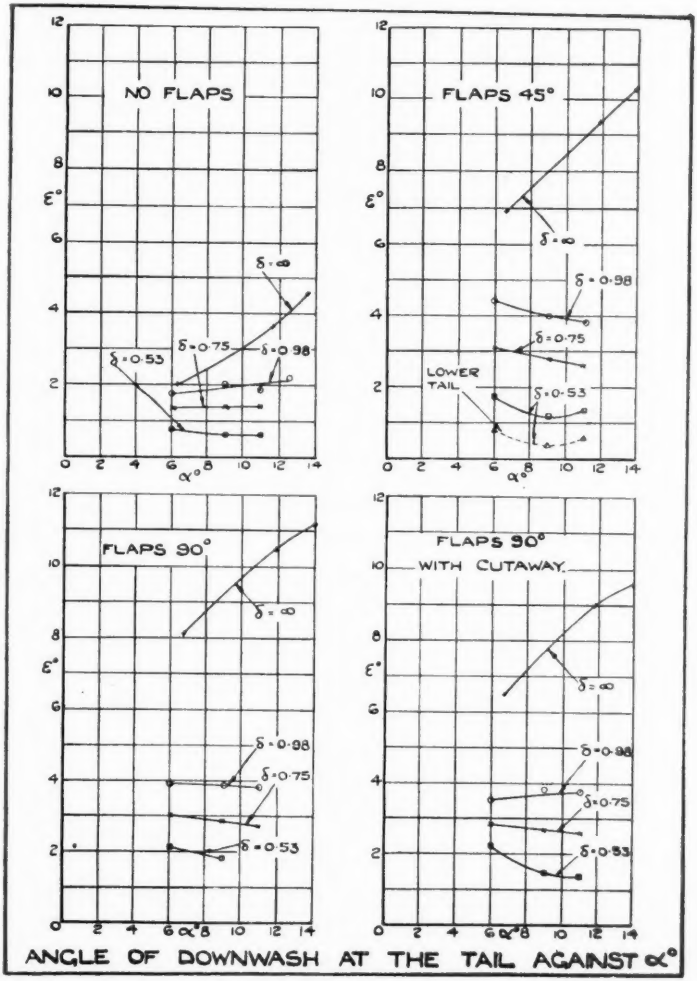



FIG. 4.

There does not seem to be any obvious means of avoiding this effect, so long as the tail is working in the downwash behind a wing which comes close to the ground when landing, unless the tricycle undercarriage comes in with its lesser changes of attitude when landing.

## PART III.

### SOME RECENT DEVELOPMENTS.

#### 1. AN IMPROVED METHOD OF BALANCING CONTROL SURFACES.

The balancing of control surfaces is of ever-increasing difficulty. Sizes, speeds, and loadings as well are soaring steadily upwards, and although I think it is true to say that Englishmen are a few inches taller than they were several hundred

years ago, their rate of increase of strength is of no material help to the hard pressed designer.

The geared tab is commonly used nowadays, but it must be applied to a control surface which is already fairly well balanced, if large losses of efficiency are to be avoided.

Irving has recently carried out some promising experiments in the wind tunnel at the N.P.L. on a form of balancing which permits of a very close degree of balance being attained, and it is much to be hoped that full-scale trials will prove equally successful. Thus it seems that the day of the true servo control is likely

FIG. 5.

to be postponed yet again, and it is interesting to observe how strenuous has been the struggle to improve aerodynamic balance of controls in order to avoid the complication, cost and weight of the servo control.

I am not forgetting the automatic pilot, whose function is to maintain a course through any weather conditions; this function is quite distinct from that of the servo control which magnifies the effort of the pilot when he is manœuvring, as for instance when landing. There is no need for me to deal with the automatic pilot, as a paper on this subject has recently been presented to the Society by Meredith and Cooke.

There is one point in connection with balancing of controls which has come up again recently, and that is the possibility of so designing the form of the balance that the reduction in stability of the aeroplane from the " controls fixed " condition to the " controls free " conditions is avoided. This effect was noticed during the war on horn-balanced rudders, and has now been used in the design of elevators, again by Irving, with success. Consider a normal tailplane with unbalanced elevator at a condition of zero lift, and for simplicity neglect the weight moment of the elevator. If the aeroplane pitches to a nose-up attitude, there will be a stabilising force from the tail, depending first on the angle of incidence of the tail, and secondly, upon the angle to the tail at which the elevator " trails " without control force being applied. The unbalanced elevator will trail, with controls free, at a slight negative angle to the tail, and reduce the tail lift below the value appropriate to the " controls fixed " case, in which, of course, the elevator does not move relatively to the tailplane. This is how it comes about that stability " controls free " is normally worse than with " controls fixed."

With Irving's method of balance, using an unshielded horn, however, the elevator instead of trailing under the conditions described above, at a slight negative angle to the tailplane, trails at a slight positive angle, thus giving the tail greater lift, and therefore producing a greater stabilising effect than with " controls fixed." This effect can be produced without over-balancing the elevator, as might be expected on first thought.

### 2. A Quickly Operable Flap.

This subject was dealt with quite recently before the Society by Fraser, and this section largely recapitulates the arguments he used, to avoid a break in the thread of the discussion.

The history of the air brake goes back a long way, but, as far as I am aware, one of the first air brakes to come into any kind of extensive use in England was that fitted during the war to the Sopwith $1\frac{1}{2}$ strutters; but, largely owing to its relatively slow wheel adjustment, and no throttle interconnection, there were a number of crashes on these aeroplanes, caused by pilots attempting to fly round

the aerodrome again with their brakes on, after having made an abortive attempt to land. Since that time other air brakes have been used, some of them quickly adjustable, but most of them not really powerful enough.

Some experiments were carried out at the R.A.E. in 1936 on a high wing monoplane, loaded to about 12lbs./ft.$^2$, and fitted with a Zap flap which really did give not only a large lift, but also a large drag. Now it must be remembered that the function of the air brake is not to slow the aeroplane down on the glide, but to make it glide more steeply, so as to facilitate the approach over an obstacle. True, the brake has an important secondary effect, and that is to "kill the float" after having flattened out to land.

Now it was found during the flight trials that the more powerful the brake, the easier was the approach to the aerodrome; the pilot simply had to fly along to such a point that he could be certain of gliding in, and then he shut off the engine, put the brake flap on, pointed the nose down at the edge of the aerodrome in the certainty that there was no possibility of over-shooting.

It was when getting quite close to the ground that a new danger began to assert itself; under the influence of a powerful brake effect, the steep glide involved a rapid rate of loss of height; the pilot saw the ground rushing up at him, and a very high degree of skill was required to start flattening out at exactly the right moment. If he started too soon, the flight path would be horizontal at some height above ground level, and the aeroplane would be losing speed so rapidly with the high drag that there was not time to get down to the ground before the stall took place; if he started to flatten out too late, the worst was bound to happen.

Thus it became clear that there is a happy mean in the steepness of the glide just before landing; neither so flat that the float is long, nor so steep that the margin for error in the actual flattening out is too small.

In order, therefore, to combine the two advantages of easy approach and easy landing, it seems that the quickly operable flap is of greater value than any scheme yet proposed. The present method of landing by putting the air brake flap on and varying the gliding angle with the throttle has two drawbacks, firstly, the pilot's view is worse owing to the more nose-up attitude when the engine is on, and secondly, that when every aid to landing is most urgently required, that is to say during a forced landing due to engine failure, the method does not work. Although forced landings are of relatively rare occurrence now, it cannot be hoped that service aircraft, operating in war, would be similarly immune, and there is much to be said for the quickly operable drag flap device, now that side-slipping on the new monoplanes has been found impracticable.

Irving's device, consisting of a double flap to obtain aerodynamic balance, has been most favourably reported upon by almost all of the pilots who flew the Falcon to which it was fitted, but it appeared that an even bigger area of flap would render approaches still easier.

The balancing of the large surface, when that surface has to be rotated through a large angle is no easy matter, and an ingenious modification to the Irving system is due to Mr. W. E. Gray; the control forces required to operate the flap with Gray's system of balance are reduced, as far as present tests go, to a very small percentage of the forces which would be required for an unbalanced flap, and this property allows the use of this type of flap on large aeroplanes without the need for a servo motor.

Before leaving the subject of quickly operable drag flaps, there is one important consideration which must not be overlooked in any design, such as Irving's, which combines the high lift and high drag devices in one single flap arrangement. Although a single lever controls the whole movement of the flap, approximately the first half of the lever travel produces a steady increase of lift up to the maximum addition attainable, with but little increase in drag, while the last half of the lever travel produces a steady increase of drag with the lift increase remaining constant at the maximum value. It is essential to provide some sort

of gate or controllable stop to restrict the lever movement to the high drag, and thus the high lift range when gliding in, as without such a stop, the pilot might easily in letting off all his drag also let off all his additional lift by mistake, with the result that he would stall instantly, if he were gliding at a slow speed and making full use of his high lift flaps.

3. Aileron Control Replacement.

Ailerons, though universally fitted, are by no means an ideal form of control; not only do they generate adverse yawing moments at low speeds, but they tend towards flutter, and also generate wing twists at high speeds. The resultant additional lift force, either up or down, is applied by the aileron at a point somewhere in the region of six-tenths of the chord behind the leading edge, instead of at, or in front of, the quarter chord point, as would be most favourable from the structural point of view. This backward point of application of the additional lift force gives rise to a twist of the wing structure, and the alteration in incidence changes the lift so as to reduce the effect of the aileron, and at very high speed the aileron control may actually become reversed.

Search has therefore been made both in this country and abroad for some completely new kind of control which would eliminate these well-known defects of the aileron as we know it now. The most promising of these have been the various forms of interceptor on top of the wing; these work by virtue of partially destroying the lift on that wing which the pilot wishes to depress. There seems to be no great harm in this slight loss of lift, which is usually small compared with the total lift on the aeroplane.

However, the difficulty which has been met with, particularly in some American tests, is the lag which has been characteristic of many of the interceptors tried; it appears that it takes an appreciable time for the interceptor to break down the air flow over the top surface of the wing and throw it clear. Again, it is not easy to fit any control surface on top of the wing, near the nose, which does not spoil the smooth and even contour of the wing at a somewhat critical place.

This investigation is continuing, but success cannot be said to be in sight yet.

4. Two-Control Systems.

Any review of the present outlook in control problems would be incomplete without some reference to the two-control system which has been proposed as a simplification to the present standard system of three controls. The subject was discussed by Alston in a paper in " Aircraft Engineering " in 1936. He points out that all normal non-acrobatic manœuvres could be performed with two controls and the only manœuvres requiring the third control are those involving deliberate sideslip. The two occasions on which sideslipping is required are, firstly, when losing height to prevent overshooting on coming in to land, and secondly, when making a flat turn, as when landing across wind, to eliminate drift.

The exponents of the two-control system argue that an aeroplane equipped with quickly variable brake flaps and a tricycle undercarriage has no need to sideslip. Height can be lost as required when gliding in to land by means of the brake flaps, and cross wind landings are safe with the tricycle undercarriage without " kicking off the drift." Where then is the need for the third control?

While it is quite possible to make good turns at the higher speeds on the ailerons alone, the necessary adverse yawing moment produced by the ailerons as the speed is reduced brings in more and more sideslip, and the need for a rudder to correct this is felt by most designers to justify the additional complication of the three controls.

An interesting variation of the two-control aeroplane is now being tried in the United States. A two-seater light aeroplane has been built by the General Engineering and Research Corporation, of Washington, D.C.; the designer is Weick, whose work on problems of control at Langley Field is well known. Weick keeps the three control organs, elevator, ailerons and rudder, but inter-

connects the ailerons and rudder in a certain ratio, and brings them in together in one control to the steering wheel, and abandons the use of any rudder bar. One result is that perfect turns can be made at the speed for which the linkage interconnecting ailerons and rudder is set, and nearly perfect turns at all other speeds. The pilot's steering wheel is also connected to the steerable front wheel of the tricycle undercarriage, and the pilot's feet operate the wheel brakes. The control system thus approximates as nearly as possible to that of the motor car, with which so many people are familiar.

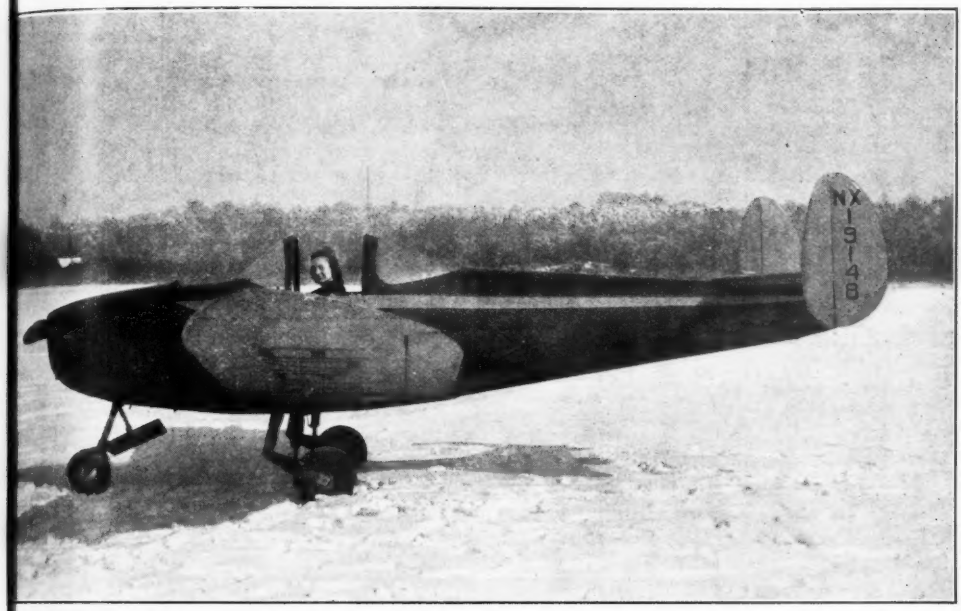



FIG. 6.

It is interesting to note that the opinion has been expressed that in bumpy weather the two-control system gives a smoother ride than the standard three-control system. Weick had some comparative tests made by arranging that his aeroplane could be converted from the two to the three-control system in a few minutes, and a number of flights were made with the two systems alternately in action. No doubt further tests of this kind will be made in confirmation, but one advantage will surely be agreed by all pilots and that is that if a turn back to the aerodrome be made after engine failure, the two-control system will look after the pilot far better than the standard; particularly is this so if a strong wind is blowing, as every pilot knows how difficult it is under these conditions to make accurate turns near the ground with no sideslip.

There is nothing really new in this system of control; it is a revival like the tricycle undercarriage, and has a most distinguished parentage. The Wrights themselves embodied it in their 1904 patent, an outline of which can be found in Volume II of "Flight."

5. FLYING MODELS.

While I hope that the methods of studying and analysing control may ultimately lead to a wider knowledge enabling designers to design their controls on a new

type without modifications, costly in both time and money, there still remains the urgent question as to what method to adopt when a new design has to be started to-morrow.

FIG. 7.

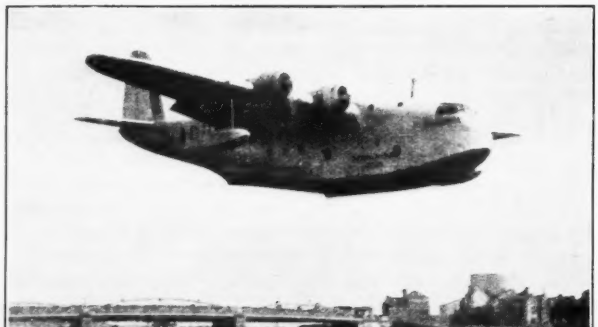


FIG. 8.

Practically all new designs represent an advance into the unknown, an advance perhaps to greater speed, or perhaps to greater size. Each designer has recourse to calculations and model tests, but most particularly to his own past experience on the full-scale with successful types which have arisen from his drawing board.

It is when he comes to deal with something bigger than he has ever made before that he may consider the construction of a "flying model," by which I mean a model large enough for a pilot to fly in, and test the controls and the stability by personal observation. One of the leading firms in this country, Shorts, have achieved splendid results with their Empire boats and Sunderlands, and not a little of this success can be placed to the credit of the flying model, the Scion Senior, which they had previously made and flown.

An examination of the relations between "model" and full-scale for true dynamic similarity has recently been made by Gates of the R.A.E. It is impossible to give all the relations here, but he shows that the wing loading should vary directly as the linear scale, and the speed therefore as the square root of the scale. The time taken to carry out any manœuvre will be less on the model in the ratio of the square root of the scale, and the control forces less in the ratio of the fourth power of the scale. Just to fix ideas, with a half scale model, the time taken to do a turn would be about two-thirds of the time on the full-scale, but the control force required would be only one sixteenth, and it is likely that frictional effects will mask force variations if attempt is made to reproduce the exact degree of balance of control surfaces on the model.

In spite of restrictions such as these, it does seem that the "flying model" has a great deal to be said for it, since alterations on a big type are so well worth while avoiding if possible. If the major changes, such as those in C.G. position, wing dihedral, tail size, etc., can be made on the model, limiting the modifications on the full-scale to minor matters, then this saving, and the greatly reduced hazard of the first test flight on the full-scale, make it impossible to leave such a scheme as this out of serious consideration.

It is interesting to note that Shorts have recently produced another "flying model," and a French firm also have thought it worth while to proceed on these lines.

## Summary.

Looking back to 1926, we see that the designer has now at his disposal a larger volume of experience than he had then, though he has but little more fundamental knowledge on control problems. Will this statement be equally appropriate at the end of another paper on control which may be presented to this Society in 1950?

I am optimistic enough to believe that the work now in progress in this and other countries will require a different summary twelve years hence, and that some, at any rate, of the hit and miss processes which now afflict us will be replaced then by straightforward design to a standard which will be more clearly seen than the somewhat nebulous "ideal control" of to-day.

## Discussion.

Mr. H. L. Stevens (*Fellow*): Aeronautical science was fortunate in having the service of a Professor who was also a very well-known and practical pilot, and who had pursued his researches to great length—even into the ground, though, happily, without unfortunate results!

Emphasising the importance of measurement, Mr. Stevens said that one could not carry out research work or gain very much knowledge unless one could put measurements of some sort on paper; but it was equally important to know why those measurements were made. It was of no use making a lot of measurements and putting measured quantities in their appropriate order on paper unless the thing which emerged at the end with good marks was in fact better than that which emerged with bad marks. Unless one knew why the various factors were measured, and knew their significance, one was merely adding to the already existing undigested information. When at Martlesham, he and his colleagues, interested in military aeroplane manœuvres, had endeavoured to measure the

forces and times involved in completing a figure 8, hoping that by means of such measurements they might be able to place the aeroplanes in some order of merit. Unfortunately, however, no such order had emerged.

Commenting upon a graph which Professor Hill had borrowed from him and had used to illustrate the paper, indicating the results of measurements on an " Avro " of the rates of rotation about the three different axes and the displacements of the controls, he said he was rather hurt when Professor Hill had referred to the information on that graph as being undigested; in fact, it was thoroughly digested, because it was directed to a definite end. It was desired to measure the response of the aeroplane to the controls when near the stall; the application of the ailerons to the right actually produced a roll to the left, and they were able to make measurements and to show the magnitude of that. Earlier a good deal of information was collected, partly with the aid of the cinema camera; that information had not helped very much, though an interesting film was produced of one aeroplane rolling in the wake of another. The experiments on the R.E.8, referred to in Professor Hill's paper, were a good example of the difficulty of the subject. They first measured the rate of banking, and then in further experiments the rate of unbanking; the latter measurement was difficult, but very important, for in the course of his flying experience he had found that the change from one bank to the other occupied a long time, whereas in fighting manœuvres one might want to make that change quickly.

They had endeavoured to compare ailerons of different chords by these two methods and, unfortunately, as far as he could remember, the order of merit was different for banking and unbanking.

He suggested that the best contribution that could be made to the solution of the problems of control was to fit an aeroplane with adjustable gearing and balances to all the controls (irreverently called the " Harmonium ") and to ask the pilots to carry out what they considered to be suitable manœuvres and set the device to give the forces and responses that were stated to be satisfactory. A statistical analysis of the results should help to make some approach to the ideal aeroplane.

Discussing the use of flap control instead of the throttle when coming in to land, he emphasised that when making the flatter approach (" rumbling in ") the machine had to spend much more time low down in the neighbourhood of the tall chimneys which seemed always to be planted around aerodromes, and disasters such as had occurred fairly recently were more likely in those circumstances, particularly in bad weather. The flap got us back to the steeper approaches of the war days.

Finally, he asked for Professor Hill's opinion, as a pilot, and as a scientist, concerning the use of irreversible controls and whether they would be required in the future.

Air Vice-Marshal R. M. HILL (*Fellow*): Professor Hill (his brother) and he had been interested in control for about 21 years. They had started work on it at the R.A.E. and had spent many hours together in the air on the study of control problems. They had struggled constantly to express in quantitative terms the sensations of pilots and to translate them into something which the designers could handle, but that had proved an extraordinarily difficult task. The pilot had to deal with many variables at one time in getting a given result, and it was extremely difficult for him to give an analysed and constructive report. It seemed essential, therefore, that the next step should be made from the scientific side; and the new arrangement of the harmoniser might help us to make that step.

Discussing the acceleration aspect of control, he said that one experienced the simplest form of it when one began to use the elevator; it became fairly extreme when finishing a slow roll, when the aeroplane had a considerable angular velocity, and then one had to pull it up level. The control was probably poor at that speed and attitude. They had come across an extreme case on a fast, heavily-loaded, twin-engined aeroplane, in which they had practised rolls fairly near the

stall simply by using the engines and elevators alone. They had had one engine full out and the other shut off, and when about one-third way round the roll, in order to pull up in time, they had had to shut off the engine which had been full open and to open the other engine full out.

It seemed, on the surface, that little progress had been made during the last 10 years; but he emphasised the words "on the surface," for he could detect signs of a more productive era. In order to overcome the present difficulties with regard to the control of aircraft, we must relate human values to quantitative measurements, and he hoped that the work of his brother would not be without result.

Professor MELVILL JONES (*Fellow*): He was in general agreement with Professor Hill, particularly with the view that the time had come when control should be studied in a more quantitative manner than hitherto. He believed that this opinion was widely held both here and in the United States. He thought that there were two reasons for this, one relating to mass production of aeroplanes and the other to mass production of pilots. Modern mass production of aeroplanes made it necessary to make elaborate preparations for the production of a large fleet, often before the prototype of the design had been flown, and it was, therefore, becoming more and more important that the prototype should not require serious modification after its first trials. Mass production of pilots meant that they must be trained by more or less standardised methods. The best method of training, particularly for instrument flying, depended to some extent upon the characteristic features of the aeroplane on which the pupil was taught and of the aeroplane which he would eventually pilot. It was therefore important that the successive types used for a given service should not differ too widely from one another or from the type upon which the pupil had been trained. He did not imply that the control characteristics of aeroplanes should be completely standardised, but rather that any change in the characteristics of a new type should be brought about intentionally with a clear realisation why it was made rather than, as in the past, as the result of a process of trial and error.

Commander R. R. GRAHAM (*Companion*): From his observation of birds in gliding flight, he thought that reversed aileron effect could be eliminated in the aeroplane if the angle of incidence of the whole wing-tip instead of just the aileron could be changed. Actually it was out of the question for birds to suffer from the reversed effect as their wings were so constructed that they could not pull down or raise the rear portion only. They were compelled to deflect the whole wing-tip. Professor Hill, he said, was doubtless aware of this. He had, in fact, employed a similar principle in the earlier Pterodactyls in which the whole chord of the wing-tip was used as a banking control. It would possibly not be worth while applying nature's method to aeroplanes owing to the added weight involved, but it would be interesting to hear his views on the matter.

Commander Graham went on to remark on disadvantage of control in modern aircraft that had been mentioned in the paper. This was that with the heavier wing loadings now used, it seemed impossible to make the modern aeroplane as handy as the old biplane. As an example of the handiness of some of the earlier aeroplanes, he recalled an occasion some years ago when he had had a mimic battle with a pilot more expert than himself who was flying a new type of fighter, whereas he, himself, was on an older type. In the old type of aeroplane he had been able to hang on to the tail of the newer type, and technically had brought it down. The pilot of the newer type of machine said that he could not get away. This meant in effect that modern fighters were at a serious disadvantage when fighting at low speeds.

Captain M. W. S. BOUCHER (*Associate Fellow*): Commenting upon Professor Hill's diagram showing the diverse requirements of different pilots in the way of balancing controls, he said it seemed that the designers would have great difficulty in satisfying all pilots, because individual pilots usually had a preference for the type of controls of which they had had the longest personal experience.

Perhaps that was rather borne out by the fact that aeroplanes of different types made by one particular firm usually had similar flying characteristics. Possibly the control adopted was largely the result of the personal preference of the test pilot.

Mr. J. HARRISON: Aeroplanes seemed to be designed for a standard size of pilot, and did not provide sufficient facilities for adjustment of the controls according to whether the pilot was short or tall. Being rather short he needed quite a number of cushions behind him to enable his feet to reach the rudder bar and several more underneath him to jack him up sufficiently high to allow him to see the nose of the machine. Once, while he was learning to fly and not making a particularly good job of keeping the plane on a level keel, he was told by the instructor to keep the top of the engine casing on the horizon. He replied that he could not do this unless he stood on the seat. Ultimately he solved the problem by aligning the exhaust manifold with the horizon.

Mr. H. B. IRVING (*Fellow*): Discussing horn balance, he recalled that the Hill brothers had had a lot to do with horns in the early days of Farnborough. Professor Hill had referred to horns on rudders, but Air Vice-Marshal Hill had had a lot to do with aileron balance and had found that horns giving a close balance had some very nasty effects when a machine side-slipped. Presumably the horn balance was adopted originally because it was about the simplest form of balance; but it was always awkward structurally, because when balancing the whole of the otherwise unbalanced moments along the aileron, by means of a horn at one end, a big torque was imposed on the aileron, and unless it was well stiffened it would twist. That trouble was accentuated in the tapered wing, where the aileron tapered towards the wing-tip and it became more difficult to put a big horn on the small end of the aileron. For those reasons the use of the horn tended to die out; but there seemed a fair chance of it coming in again, to perhaps a limited extent on elevators as a means of helping the designer out of the rather difficult stability problem arising from the fact that C.G. limits seemed to get wider, and the C.G. had an awkward propensity of wandering back and spoiling stability.

A very interesting point, with regard to the horn balance and stick-free stability, was that where there was a horn on the elevator there should be, theoretically, no effect on stability when the pilot had the stick fixed and was holding it in the hand; but he believed that in actual practice, even when the pilot was holding the stick, he felt the stick-free stability effects. Probably that was because the pilot did not hold the stick absolutely rigidly and the elevator was subject to very small movement; further, there was always a certain amount of slackness and elasticity in the control system. But however that might be, he did not think that on elevators the horn was the kind of thing that the designer would have to rely upon entirely for balance, and probably a sensible solution would be to secure part of the balance by setting back the hinge, and to complete the balance, at any rate as nearly as possible, by using a comparatively small horn to take care of the stick-free stability. The designer should not use an ordinary unbalanced elevator, without horn or set-back hinge, and rely on the geared tab alone to secure balance; if he did that, he would lose more stability than would be lost with a completely unbalanced elevator. There was some interesting information on that matter in an article by Professor Metcalfe in "Aero Digest," August, 1934. The article referred to a series of experiments on elevator balance with a series of tabs of different sizes and also with a series of different percentage set-backs.

With regard to the balancing of controls generally, he suggested we were reaching a stage at which some form of power operation must be considered seriously by the designer. He believed that one or two of the large companies in America were already using power controlled operation. They used a Sperry gyro motor which worked a pump; the pilot controlled the machine in the ordinary way with the control column, but this actuated the pump. He had it on fairly

good authority also that the Douglas Company were going to change over to power operation in the D.C.4. In the original version of that machine they had tried to get away with aerodynamic balancing, but it was not good enough. That was borne out by a statement in an article by the Earl of Cottenham, published in "The Aeroplane" not long ago, to the effect that on the first flight of the D.C.4 both pilots had to exert a considerable effort on the control in order to flatten out for landing. Even if power operation were adopted, however, it would always be worth while providing a certain measure of balance, if it were obtained simply enough; if the controls were balanced to some extent, the power required to operate them would be reduced.

Commenting on Professor Hill's reference to a new method of balancing, on which the N.P.L. had been working, he said that so far as this country was concerned, W. R. Andrews had got in first with the idea. Unfortunately, however, the Junkers Company had got in earlier still.

Mr. B. S. SHENSTONE (*Associate Fellow*): It was certainly a good thing to know what control forces the pilots wanted, but it was an entirely different matter to provide for those control forces in an aeroplane; at present it was quite impossible to design a control with a given hinge moment. On one occasion he had made an analysis of wind tunnel tests and had found that for a certain aeroplane the forces on rudders and elevators were so large that the pilot simply could not move the surfaces. If that aeroplane had not at the time been flying satisfactorily, grave doubts would have arisen with regard to its practicability. It was wise to beware of wind tunnel tests; the alternative was to carry out full-scale tests, and that was very much more difficult and expensive. The full-scale work done recently in Holland by Dr. Van der Maas was very important in this connection, and he asked whether that work had been published, for he had not been able to find a record of it.

Surely, he said, the use of servo motors was a lazy way of solving the control problem. Dornier had used manual control on his 50-ton DO.X., although the wings on that machine were much larger than the wings that were being considered for new machines to-day, and if Dornier could get away with it in 1929, surely other people could do so on the present-day machines. However, we must first obtain the information on which to base design, so that, perhaps, we could use servo motors until we were able to design the controls sufficiently light, and then scrap them later when we had learned to do without them.

Dr. G. V. LACHMANN (*Fellow*): The problem of control, about which little was known, was very tantalising from the designer's point of view; at the same time it was a very fascinating problem, because it seemed to be the only problem in design into which the human or artistic touch entered. He had tried to extract information from test pilots as to what they really wanted, especially with regard to harmonising controls, but he had found that the task of designing controls according to a pilot's description was about as hopeless as that of trying to buy a lady's hat according to description! Therefore, he had tried to arrive at a solution in a different way. Obviously, it was impossible to solve the whole problem perfectly, for there were very many unknowns; but a partial and fairly satisfactory solution might be reached by reducing the number of criteria to, say, four, and dealing with them step by step. Much had been said in this country and in America and Germany about harmonising the actual forces on the stick; but that by itself was of no use. Two things which had to be co-ordinated were force and response. Data was available concerning the co-ordination of forces. For elevators and ailerons there was a ratio of 3:1. He had tried to co-ordinate the control forces with angular movements; it could be done only by calculation, but it had worked fairly well. Of course, it was only a partial solution.

The two most important things to co-ordinate were the elevator and aileron; he did not think it was so important to try to harmonise the rudder also. When in America about two years ago he had been very pleased to meet Weick, who was a very great expert on those matters and had more or less agreed with that idea.

He had said also that the Americans had adopted a simpler kind of yardstick. What was really required, from the point of view of the designer and the test pilot, was accurate measurement of control forces and their co-ordination with the angular movements. It would be a good thing to measure those forces and angular movements on an aircraft having good characteristics, and to make a comparison with the forces and movements on a machine having particularly bad characteristics. As Weick had pointed out, it was not necessary to hit the bull's eye exactly—especially as no one seemed to know just where it was—but it was important to be on the map. It was important, of course, that in a small aircraft the controls should be reasonably light and pleasant. But in respect of large aircraft great care must be exercised, for there was risk of difficulties arising from the carrying of exceptionally heavy weights—and it cost a lot of money to play around with a prototype on the ground for a long time.

Mr. W. E. GRAY (*Companion*): He commented that Professor Hill had clearly indicated the position of the bull's eye when he had said that the pilot should always be able to impose his will upon the aeroplane. If the pilot could do that, the machine was satisfactory, but otherwise it was not, and he did not think that the position was vague, as Dr. Lachmann had suggested. The trouble so often was that the pilot could not impose his will upon the aeroplane under all conditions of flight.

The point made by Professor Hill, that improved control would lead to higher speeds, was often lost sight of, and should be emphasised. If a machine had a very good top speed performance and yet the pilot dare not bring it in without a very large margin of speed in hand because he was afraid of stalling, or wing dropping, the designer had really failed in his object.

Discussing the use of the variable air brake from a very limited experience he considered that it was quite sensible to point the aeroplane at the edge of the aerodrome, and, if the speed were becoming excessive, to use the brake as a brake. Otherwise, presumably, the pilot must choose the speed of approach and keep guessing at the angle, varying the brake in order to bring the angle to what was required.

He asked whether there were any further developments in regard to boundary layer suction as an alternative method of lateral control.

Finally, in a reference to his own modification of Irving's divided flap, Mr. Gray drew an approximate diagram showing the control forces needed.

(*Communicated.*) The lecturer's reference to the war-time stability experiments at the R.A.E., as an example of theory and practice getting out of step, seems unfortunate in lending weight to the quaint view that theory and practice are very different things; the machine had never even been mathematically stable owing to gross incompleteness of the theory. When reason attempts an advance on practice it is necessary to verify its soundness by doing a flying test.

Regarding two-control systems it is not clear how a pilot keeps a compass course in bumpy weather, without discomfort to all on board.

Few will quarrel seriously with the truth of his condemnation of the aeroplane's habits at the stall, but it seems very shocking that after 35 years of experimenting since the days of the Wrights the chairman of the Stability and Control Sub-Committee of the A.R.C. should have to use such scathing remarks about the aeroplane's stability and control at the stall as he does in section 2 of part 1 of the paper. For many years we have had a Director of Scientific Research—can it be that there has been too little Stability and too much Control in the directing of research on the aeroplane?

Mr. F. RADCLIFFE (*Associate Fellow*): He suggested that the American recommendations put forward by Warner should be amplified, so far as we were able to amplify them in this country, and that a further meeting should be arranged at which the pilots should be invited to indicate their reactions and requirements, and the designers could indicate how far they could go to meet those requirements. Although the problem had been discussed systematically for about three years, we

were still in the clouds and were likely to remain there for some time. In view of the very slow rate at which progress was being made, he did not share Professor Hill's optimism, and he urged that all interested in the problem should pool their brains and resources in endeavouring to find a solution.

(*Communicated.*) Since the " target " at which the designer is aiming is vague, due to one's inability to define it rigorously, it would appear that the solution of the flying control problem will allow only of a reasonable degree of precise definition and analysis and in the end practical testing alone will indicate whether or not the desired objective has been attained. On this assumption, therefore, it is suggested that it would prove very useful to allow a number of different types of pilots to try out an aeroplane whose flying controls are admitted by an official flight test station to be beyond reproach.

Such an aeroplane, in the fighter class would be the Gloster Gauntlet, and for the other classes he was sure there would be available others which are equally satisfactory. He was interested to find how closely the general characteristics of the Gauntlet compared with other satisfactory machines of the same category, and this led him to make the suggestion that, if an analysis were made of different aeroplanes of the same class with a view to finding out where the main differences in characteristics occurred, some progress might be made in this problem.

It is interesting to note in passing that during his association with Mr. Folland at the Gloster Aircraft Co., they covered a wide range of aeroplanes in which they were able generally to get good results with only minor final alterations, and this they attributed very largely to giving very careful consideration to wind tunnel data, gearing ratios, and, above all, to ensuring that more than minimum strength requirements were met, for they felt that stretch of cables and distortion of surfaces must be reduced to a minimum.

The calculations and investigations they habitually carry out on control systems would be considered by some to be very elaborate, but their experience has led them to the belief that their results more than justified the time spent. They had used wind tunnel data quite extensively, and their results have borne out the design data derived from these tests.

He would like once more to suggest occasional meetings between the stability and control panel and the designers, so that the problems can be dealt with much more energetically than by the questionnaire method, which seemed to him to lack soul and enthusiasm.

In the meantime, the designer is making his assumption for " designing " his control system for his new prototype, and he has to fall back on his past experience. Why not let that experience be pooled? The sum total of that experience would surely enrich the individual designer.

Squadron Leader H. P. FRASER (*Associate Fellow*): He emphasised, in view of the remarks made concerning the " mass production " of pilots in war time, the increasing importance of producing aeroplanes all having more or less the same control characteristics. In the past it was possible to spare the time to train pilots up to a standard, which enabled them to fly any aeroplane, whether or not it was on the " target " as described by the lecturer. But now it was imperative to keep the time required for training down to a minimum, and no one type of aircraft should be markedly more difficult to fly than another. This made the study of aircraft controls, as indicated by the lecturer, an urgent matter in order that all aircraft should come on the " target."

Another matter he discussed from the pilot's point of view was that of the response of the aeroplane to the control movements made by the pilot. Whether an aeroplane was a light fighter or a heavy bomber, the pilot expected to be able to do comfortably and without undue exertion certain definite manœuvres; in order to carry out those manœuvres, he expected the aeroplane to respond to the forces he applied to the controls at a certain rate. Thus there was a relation, not necessarily between the size of the aeroplane and the response to the controls,

but between the duties it had to perform and its response to the controls. If a pilot were expecting a fairly slow response and, on moving the stick, found that it moved over easily and quickly to the end of its panel, but only produced a very slow movement of the aeroplane, the relation between the weight of the control and the response to it was not satisfactory, and a somewhat heavier control was wanted. It was not suggested, of course, that the weight should be so great that the pilot should exert considerable physical force; but he would expect to find some relation between the weight on the controls and the response. On the other hand, when flying a light aeroplane the pilot expected a quick response, and it was most disconcerting to have to push hard on the stick and to have to hold it displaced for some time before the aeroplane responded. The problem of the "pleasant" aeroplane was tied up with the two relations—first, the relation between the response and the duties for which the aeroplane was designed, and secondly, between the weight of the controls and the type of response which the pilot expected.

(*Communicated.*) He would like to contribute a few remarks in writing arising out of Squadron Leader Bonham Carter's reference to the variable air brake. Squadron Leader Carter stated that he preferred to keep the flap in a fixed position and use the throttle during a landing because the flap could not extend the glide indefinitely as could the throttle. But there is no reason why the throttle cannot be used to extend the glide even when there is a variable air brake fitted. The only difference is that the pilot can at the same time remove some of the drag if he wishes to do so in order to obtain a livelier response to the throttle.

With increasing wing loadings the need for large low drag flaps for take off will become greater. If one continued to use high fixed drag and the throttle for landing, one would find that the throttle would become less and less effective in stretching the glide. Then, when one has to go round again or motor in some distance, the drag will be too high (compared with the wing loading) for this to be a safe proceeding even with full throttle. Unless, therefore, some provision is made for reducing the drag quickly without reducing the lift, the maximum value of the fixed drag may have to be set at too low a figure to make possible the continuance in future aeroplanes of the present advantages of being able to glide at a steep angle, if and when necessary. The fixed drag and throttle approach is satisfactory now, but it will have, for the reasons stated above, increasing limitations as wing loadings become higher. That is why, unless some revolutionary inventions are forthcoming, one looks to the variable air brake as the means of preventing the approach becoming difficult. Finally, let him again emphasise that the throttle can still be used for stretching the glide indefinitely if the pilot so desires.

Squadron Leader D. Bonham Carter: Pilots required controls that worked at all speeds, but they were not getting them at present. In some aeroplanes the rudder control could not be moved at 200 m.p.h., and that was not good enough. The same remarks applied to the elevators, for one could with difficulty get some aircraft into a dive at speed others got out of the dive. If the designers could provide controls to work satisfactorily at all speeds, they would have done a great deal. When they had done that, they might consider whether the controls should be heavy or light.

He suggested that if designers realised how very much the efficiency of control was wrapped up in stability, they would be at the root of the problem of providing controls which would really work. Pilots would really like an aeroplane with adjustable stability. At present often the pilot was fighting against stability, because when he wanted to dive, the stability was trying to prevent it; it was also difficult in the stable aeroplane to put the tail down when landing. A good diving bomber, therefore, should not be stable at all speeds. The sooner the designers realised that a too stable aeroplane both laterally and longitudinally should not be their sole aim, for it introduced difficulties in regard to control, the sooner would they be able to provide the aircraft which the pilots wanted.

Crossing swords with Professor Hill in regard to the desirability or otherwise of the use of the adjustable flaps when approaching to land, he suggested that if one could get so far in the design of the adjustable flap that it was definitely connected with the throttle, and came into action only when the throttle was fully closed, he would welcome it; but he did not welcome an adjustable flap to play about with in order to adjust the angle of approach as a regular means of coming into an aerodrome. It would not do what the throttle would do. It would not extend the glide indefinitely; one wanted to do that at just about the time the aeroplane was about to hit the hedge on the edge of the aeroplane. If one reduced the drag at that time it would carry the aircraft some way towards the aerodrome, but not the full distance. It was then that one required the throttle. He suggested that, for the training of pilots in a hurry, it was best to use aeroplanes with plenty of drag and to allow the pilots to overcome some of the drag with the throttle. If the pilot had to make a forced landing, he would not find it difficult, with a high drag aeroplane, to get into the space in which he wished to land; such an aeroplane came down at a steep angle, and by a very slight turn would lose a lot of height. He did not agree that all aeroplanes should be similar to handle. His experience was that when once a pilot had learned to fly he would be able to handle most aeroplanes, whether the controls were heavy or light. Of course, the controls should all work in the same way; but he had not heard of even a young pilot who had got into grave difficulties through flying an aeroplane which varied from one he had flown previously, provided, of course, that the second aeroplane had no obvious vice.

THE CHAIRMAN: In March, 1939, Mr. Baumhauer would lecture to the Society on testing stability and control. That lecture would provide an opportunity for further discussion.

### REPLY TO DISCUSSION.

Professor HILL: He wondered what had become of his enemies. He had expected them to be swarming around him breathing fire and smoke; but most of them had expressed agreement with the views he had put forward in his paper.

In acknowledging that Mr. Stevens had very kindly lent him a number of slides for the purpose of illustrating the paper, he said that Mr. Stevens had tripped him up, fairly and completely, with regard to the slide showing the results of measurements made on the Avro machine. It was unfortunate that he had shown that particular slide at the moment of complaining that a good deal of information which had been collected had not received as much attention as it might have received. The information on that slide had been thoroughly digested since, and he thanked Mr. Stevens for correcting the error.

He was glad of Mr. Stevens' reminder of the conflicting results of the old experiments on the R.E. 8 ailerons, and he felt that this kind of answer well illustrated one of the many complexities of the whole problem of measurement, and provided yet another argument for establishing a sound quantitative measuring technique.

With regard to irreversible controls, he said he regarded them as inferior to other means to solve the problem of flutter.

In reply to Air Vice-Marshal Hill's description of the technique of rolling a twin-engined aeroplane by differential use of the throttles, and the large lag which was experienced, he felt on sound ground in saying that this large time lag entailed long practice coupled with the highest degree of piloting skill if a perfect finish to the roll was to be achieved; this surely was an excellent illustration of the undesirability of lag in any control.

Commenting on Professor Jones' reference to quantitative measurements made in America, he said it would be a tragedy if America were to leave this country behind in that respect, as it had left us behind in some other branches of engineering.

He was very glad to have Professor Jones' strong support in the attempt to work towards a more uniform feel for the controls of all types of aeroplane.

As to the suggestion made by Captain Boucher that a pilot always preferred to fly a machine having controls similar to those of the machine on which he had learned to fly, he said that similarly each motor car owner felt that there was nothing like the car he owned, regardless of its real value; one became accustomed to a control and felt happy with it, and in an emergency, one had a better chance when handling the type that one knew best.

Dealing with Lieut.-Commander Graham's reference to the manner in which birds moved their wings, he suggested that the problem was largely a matter of size. With large size there was large inertia, which led straight into trouble. As aeroplanes became bigger, the pilot became relatively smaller and smaller, until on a large aeroplane of to-day the pilot was almost too small to see. That fact had a powerful influence on one's outlook on control problems.

Commander Graham had raised the old controversy as to the relative fighting power of the low powered lightly loaded aeroplane and the high powered heavily loaded type with higher performance. It was quite true that the lightly loaded type could turn quicker, and his heavier opponent could never get on his tail if the light type were at all skilfully handled. A good example of the lightly loaded fighter was provided in the Great War by the Sopwith Pup; although this type did magnificent work in the hands of many very fine pilots, its peculiar qualities were never reproduced again; some satisfying explanation of this must be produced before, in his opinion, Commander Graham's argument could carry real weight.

Replying to Mr. Irving's reference to the power controls on the Douglas D.C. 4, he suggested that that particular machine did not hit the bull's-eye of the target at which all were aiming, but was just about falling off the edge, and he was sure that the company was effecting improvements which would bring it more towards the centre. But in any case, he regarded it as rather a confession of failure to have to use power to operate the controls in a machine of that size. The only large type with heavy loading which he personally had flown was the Short " Sunderland," and the controls of that machine were extraordinarily good, and seemed to indicate a good margin for dealing with yet larger types.

Dealing with Mr. Harrison's plea for greater facilities of adjustment to accommodate the tall or the short pilot, he said there used to be, and he thought there still was, a 4-inch adjustment of the seat and rudder bar. Even this amount of adjustment was not sufficient to accommodate every conceivable size of man, but it was extremely annoying to the designer to have to provide even as much as this. If only Air Force pilots were graded as to height in the same manner as the City Police, how simple it would be for designers.

With regard to the balance of controls and the doubts which Mr. Shenstone had cast on the possibility of successful design based directly on wind tunnel experiments, he agreed the problem was very tricky, and he felt that the flying model might help in its solution, for big machines, at any rate. The difficulty was to make a true dynamic flying model, for, as he had said in the paper, the control forces increased as the fourth power of the size, so that it was difficult to assess these forces accurately. At the same time, one could be sure from a flying model of, say, half size, that one would not need the dangerously high control forces that, according to some reports, were required on the Douglas machine when landing.

Replying to Dr. Lachmann, he said he had stated in the paper that we were seeking to obtain, with the " Flying Harmonium," the optimum " feel," and these tests would include the important factor missing from the ground tests, viz., the response of the aeroplane in its relation to pilots' effort. The word " feel " had, in his view, a very limited meaning unless response was taken into account, and certainly he had intended to convey the idea that we needed to

correlate response with the measured forces. He was glad Dr. Lachmann had brought this point up and emphasised its importance.

In reply to Mr. Gray, he was not aware of any experiments involving the use of boundary layer suction as a control.

With further reference to Mr. Gray's written contribution as to the relation of theory with practice, perhaps a misunderstanding had arisen owing to insufficiently clear definition. As Mr. Gray himself points out, the theory which had been applied in the case quoted was an incomplete theory, and unfortunately the factor omitted was one of the most important and vital ones. He had certainly made some scathing remarks about the behaviour of certain aeroplanes at the stall, and Mr. Gray had replied with some scathing remarks as to the capacity of the Director of Scientific Research. He did not believe anyone would seriously contend that other countries had done a great deal more than we had in attempting to solve these problems, and perhaps it would be more fitting to transfer the scathing remarks to the level of intelligence of the human race as a whole, seeing how slow it was in making progress.

He did not know how much further we could get at this stage as the result of a discussion by pilots of Warner's proposals. He felt that we had already gained a general idea of how the pilots felt as a body, as the result of the A.R.C. questionnaire, and he felt that the next most useful step was to try fully in the air the " Flying Harmonium." It had been suggested by Mr. Radcliffe that we were still in the clouds; however that might be, he felt that if we could get the " Harmonium " into the clouds we should then really begin to learn something! Surely if we can get a large number of pilots to " tune the Harmonium," we shall have that pooling of resources that Mr. Radcliffe so rightly urges.

Mr. Radcliffe's suggestion that some type of aeroplane in each class be set up as a standard may be regarded as an elaboration of the work now going forward at the R.A.E. Perhaps it was rather easier to start with a medium-sized type, than to attempt the single-seater first, with its extremely rapid rate of manœuvre.

He was glad to be in a position to endorse from his own personal experience the claims Mr. Radcliffe had made for the excellent control qualities of such types as the Gloster Gauntlet, and he felt that the discussion had been valuable in drawing from Mr. Radcliffe an authoritative statement describing the amount of effort which was ungrudgingly spent in the achievement of such splendid results.

He agreed that a questionnaire lacked soul, but every member of the Stability and Control Sub-Committee had, if not plenty of soul, certainly plenty of enthusiasm, so needful in work of this kind; many visits to firms were paid by these men, and that form of contact was felt by them to be most valuable; judging from the cordial welcome invariably extended to them by every firm, he felt that the efforts of the Sub-Committee and those working with them to come to a truer understanding of the problems were recognised by all designers.

Squadron Leader Fraser layed down that " the pilot . . . expected the aeroplane to respond to the forces he applied to the controls at a certain rate." This was what was to be measured in the flying experiments outlined, but it was interesting to speculate as to why the pilot expected a " certain rate " of response. Was it what he was used to, or how did he create some standard in his mind and judge by reference to it? Was it perhaps what he thought some imaginary and perfect aeroplane might do? Once these standards were capable of definition numerically, we should be well started on the right road.

The remarks of Squadron Leader Bonham Carter, which were directed to the designers, should be very closely pondered. One of the Pterodactyls had had adjustable stability, but it was not possible to discuss that question fully in the time at his disposal. One could secure different degrees of stability by making the passengers and crew walk from one end of the machine to the other, and he had resorted to that in the course of landing tests in the 1920 competitions at

Martlesham. By making the crew sit in the tail, the Handley Page W.8 in which he was flying had been landed in an extraordinarily short space, far shorter than other competitors in the class.

The adjustable flap problem was worthy of much more consideration than could be given at that meeting, but a number of valuable written contributions had been forthcoming. He welcomed the opportunity which the meeting had afforded pilots to express their views; they had thrown new light on the problem of control, and the liveliness of the discussion constituted the greatest possible compliment that the meeting could have paid him.

On the motion of the CHAIRMAN, a hearty vote of thanks was accorded Professor Hill for his paper.

# A METHOD FOR THE PHOTOGRAPHIC RECORDING OF TAKE-OFF AND LANDING PERFORMANCE.

By J. B. Douglas, B.A.Sc., A.F.R.Ae.S., and
J. B. Mills, B.Sc., B.E., Grad.R.Ae.S.

1. Summary.

This method has been designed to give all necessary performance data, concerned with the take-off and landing of aircraft, in a cheap and efficient manner. The complete path of the machine from the start of the take-off run to beyond the screen is recorded on a single photograph and from it the reduction of the data is done readily and simply. In the case of a take-off the data obtainable is as follows:—

(*a*) Take-off run.
(*b*) Nature and length of the transition.
(*c*) Height at any screen.
(*d*) Distance, velocity and acceleration at any point from the start.
(*e*) Angle of climb.
(*f*) Rate of climb.
(*g*) Any irregularities in the flight path.

Similar data can be obtained in the case of a landing. Any information may be extracted independently and the photographic negative filed for future reference.

The camera used is simple and inexpensive, both in construction and subsequent use. Four persons at present form the total ground staff and with an improved camera now under construction one of these is eliminated.

The accuracy obtainable with the present apparatus is sufficient to fix the position of the aircraft to within $\pm 2$ feet. Once the initial work has been carried out on any aerodrome, future use of this method has been found to be simple, quick and sufficiently accurate for all normal requirements.

2. General Description of the Process and Apparatus.

This method was developed by the de Havilland Aircraft Co. in connection with research into variations in take-off and landing of different aircraft on various aerodromes and under numerous conditions of loading, aerodrome surface and atmosphere.

The photographic recording is done by means of a single camera and the complete run is recorded on one photograph on a stationary film.

The camera used has been developed from a panoramic type, popular many years ago, in which the lens rotates about a vertical axis and the film is arranged to form the arc of a cylinder with the axis of rotation as its centre. This camera was modified by fitting a shutter to the lens which could be operated by remote control whenever required and would give an elementary exposure each time in the form of a vertical strip on the stationary film, the elementary strip being defined by a hood attached to the rear of the lens, as shown in Fig. 1.

If an aeroplane were taking off and the lens was kept pointed at it continuously whilst exposures were made at known intervals of time, then each exposure would give a vertical strip of panoramic view with the aircraft also included as shown in Fig. 3*b*. Each of these images has been obtained at a known time from the start, so all necessary data is readily obtainable.

The camera must always be in the same position relative to the surveyed take-off run, and this allows the use of a master grid which is superimposed on each

take-off or landing negative and gives the co-ordinates of the machine in each strip. This grid is shown in Fig. 3*a* and as used is a transparent photographic positive print which is superimposed on each take-off negative by matching up corresponding irregularities in the horizon. This horizon is common to both, as the grid is drawn on a panoramic view taken from the standard camera position. The grid is virtually positioned along the centre line of the take-off run and should the machine deviate either side of its true course, this is noted and measured by an observer standing behind the machine (for a take-off) and corrections to the results are applied, found readily from simple charts, *e.g.*, Figs. 6, 8 and 9.

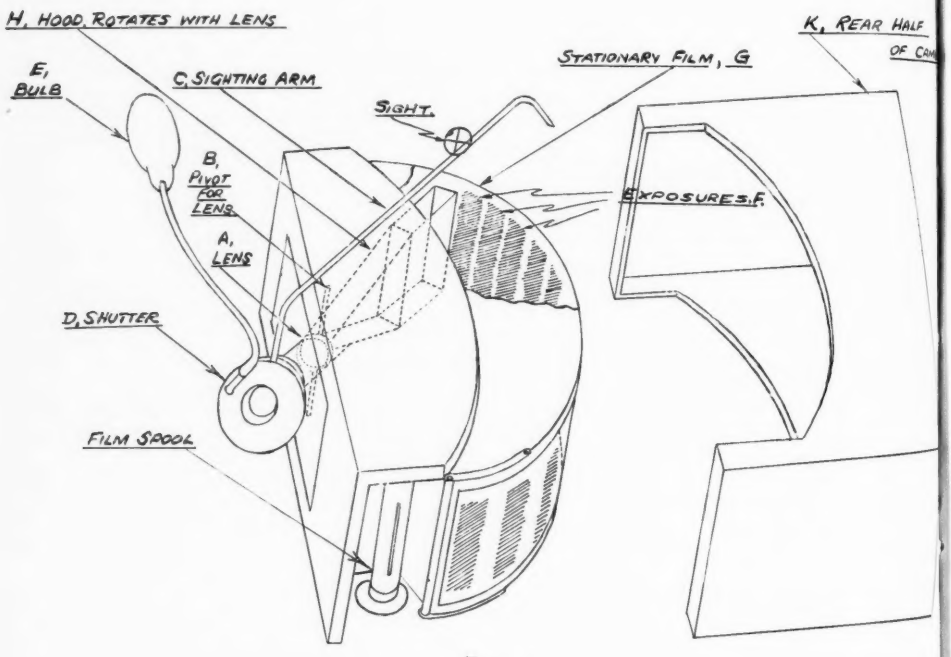



FIG. 1.

*Diagrammatic sketch of camera.*

The possibility of errors due to such deviations in the path of the aircraft has been explored and also their probable magnitudes, and from this it seems that the best position for the camera, if the errors above mentioned are to be as small as possible, coincides with the most convenient position, which is halfway between the start of run and the screen. However, the errors are easily corrected and the results obtained on a production basis.

It is thought that this method gives the easiest way at present possible of obtaining full take-off and landing data. All necessary information relative to the construction of the master grid, correction charts and reduction of results is included.

One very important result which is obtainable by this method is the magnitude and nature of the transition period and it is considered that the point where the aircraft starts to climb is of far greater value than the point where the wheels leave the ground as this latter point is very susceptible to variations in pilotage and ground irregularities.

A readily obtainable curve and algebraic expression for the velocity and acceleration of the machine in terms of time from the start, through the whole run up to the screen, is of considerable help in the analysis of take-off performances and it seems that there is no other convenient method for obtaining this. An example is shown in Fig. 10.

3. THE CAMERA.

The camera as used at present is shown diagrammatically in the isometric sketch, Fig. 1, and includes the main essentials. Also a photograph of the prototype camera in Fig. 1*a*.

FIG. 1*a*.

*The prototype camera.*

*The sighting arm, bulb attachment and shutter can be seen. The white lines on top of the camera indicate the angular movement obtainable with the rotating lens. In operation one person keeps the sighting arm pointed at the aircraft under test and a second operator presses the bulb attachment at known times, using a stop watch. The second operator will be eliminated with the improved camera being designed by the Air Registration Board.*

Referring to Fig. 1, the lens (A) is free to rotate on a vertical pivot (B), and can be turned and pointed at any required object by means of the sighting arm (C). The lens is fitted with a shutter (D) which can be worked by a bulb attachment (E) giving elementary exposures (F) on the stationary film (G) as the lens follows a moving object around. The width of these elementary exposures is kept small by means of the hood (H) which rotates with the lens and shutter, preventing fogging of the unexposed portions of the film.

On completion of a run the whole length of exposed film may be wound off on a conventional box camera spool, leaving a new length for the next run. It will thus be seen that the film is stationary during a run and is placed in an arc of a circle with the lens as centre. The rear portion of the camera (K) is removable to allow the changing of film.

This type of camera can be quite conveniently made by modifying a No. 4 " Panoram " Kodak, Model B, the modifications consisting of fitting a shutter with remote control, a sighting arm and an extension of the hood of the standard

camera so that it comes within one-eighth inch of the film to prevent reflected light from an elementary exposure fogging the remainder of the film.

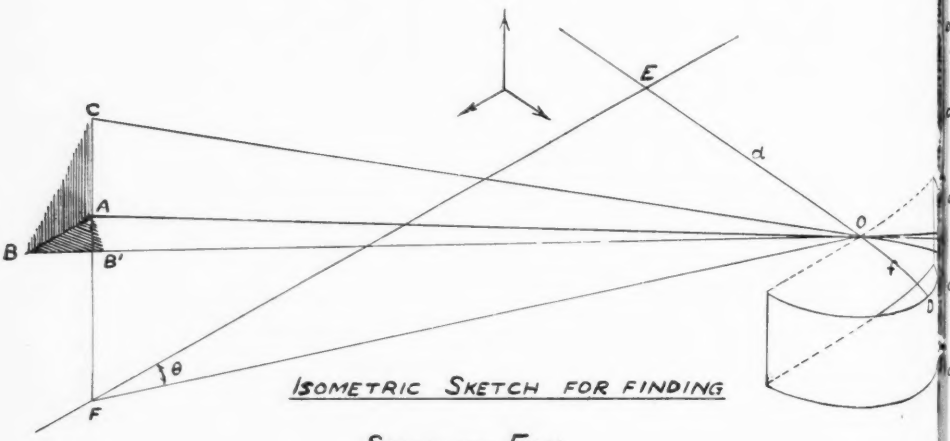
The Air Registration Board are at present constructing an improved camera incorporating all improvements suggested by this prototype which has been described only to give an outline of the bare essentials and a method of making a very cheap camera which will give consistent results. Desirable points may be summarised as follows:—

(*a*) A firm base with levelling facilities, such as a surveyor's tripod.
(*b*) The camera to be as near the ground as is consistent with the operator's comfort. This height must always be the same.
(*c*) A method for eliminating overlap of the exposures.
(*d*) An automatic timing device.
(*e*) Enough film in the spool for a number of runs without changing.
(*f*) Facilities for quick change of film.

4. Operation.

At present four persons are required for full measurements by this method. One man for atmospheric observations, one to note deviations from the desired line of flight and two men to operate the camera, of whom one points the lens at the aircraft and the other takes exposures at known intervals, using a stop watch.

With the improved camera one of these men will be eliminated as the exposures and timing happen automatically and the pointing arm has just to be kept on the aircraft under test. It thus seems that this method of measuring take-off offers an economy in personnel over normal types of measurement.




ISOMETRIC SKETCH FOR FINDING SCALE ON FILM

Fig. 2.

5. The Master Grid.

Due to the film in the camera curving and the patn of the aircraft under test being in a plane, the scale of the photograph will vary from point to point. Referring to Fig. 2, the curved film and the line of flight are shown diagrammatically in isometric projection. The point "*O*" represents the centre of the lens, and the distance *OD*, *f*, is the focal length of the lens. The theoretical line of flight of the aircraft is in the plane *EFC*, and the perpendicular distance from the camera to the line of flight is denoted by "*d*."

Take an arbitrary point $A$ in the plane of flight and vertical and horizontal distances, $AC$ and $AB$ respectively, in this plane. $AB$ and $AC$ will have images $ab$ and $ac$ on the film and let the angle $EFO$ be $\theta$.

Then $$ac/AC = Oa/OA = (f/d) \sin \theta \quad . \quad . \quad . \quad . \quad . \quad \text{(i)}$$

Draw $AB'$ parallel to $ab$ and as $AB$ is small, $AB' = AB \sin \theta$ approx., and

$$ab/AB = (ab/AB') \sin \theta = (f/d) \sin^2 \theta \quad . \quad . \quad . \quad \text{(ii)}$$

If the vertical and horizontal lengths $AC$ and $AB$ are taken equal, we have from (i) and (ii)

$$\begin{aligned} ac &= AB\ (f/d) \sin \theta \\ &= ab\ (f/d)\ (\sin \theta / \sin^2 \theta)\ (d/f) \\ &= ab \operatorname{cosec} \theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(iii)} \end{aligned}$$

This expression (iii) gives the relationship between the horizontal and vertical scale at any point on the film. It will be noted that the height of the point $A$ above the camera does not enter into any of the expressions, hence the scale of the photograph remains unchanged vertically at any one point or, in other words, verticals in the plane of flight remain verticals in the photograph.

Thus to obtain the Master Grid scale it is only necessary for some signal to be photographed, from the standard camera position, at successive intervals along

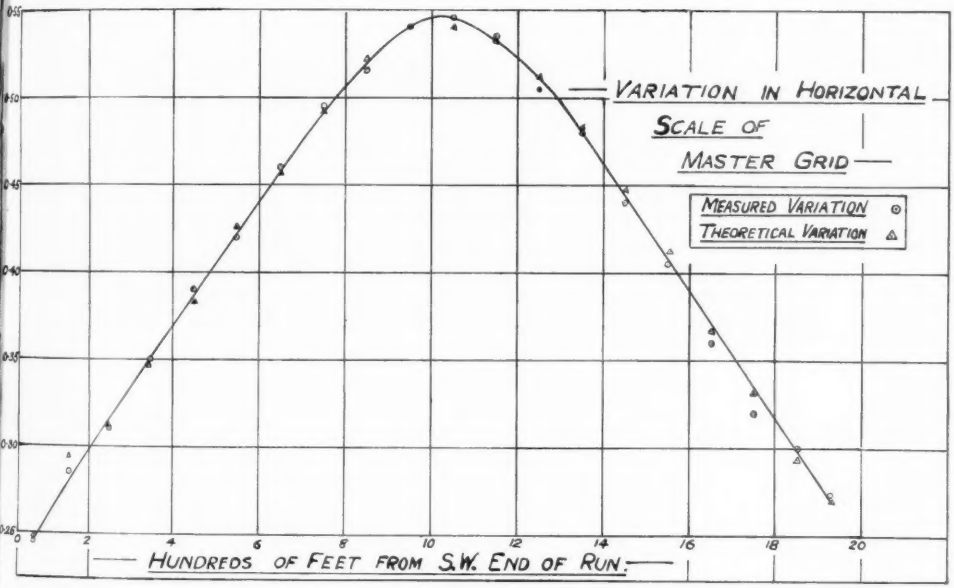



FIG. 3.

the line of flight and the corresponding horizontal intervals on the film can be ascertained, *i.e.*, $ab$. The vertical scale is then obtained from this by multiplying each horizontal interval by the appropriate value of cosec $\theta$. This method for finding the scale is more definite than working from purely theoretical considerations and the results obtained, compared with checks by other methods, have shown that an accurate grid is obtained in this manner. The Master Grid is shown in Fig. 3*a*.

6. ACTUAL METHOD ADOPTED TO CONSTRUCT MASTER GRID.

The camera was set up mid-way between the start and screen of the normal take-off run and offset 300 yards from the line of flight. Two men in white coats

and holding a white signal were photographed at successive 100ft. intervals along the flight line. The distances between successive images of the men on the film were then measured, plotted and compared with the theoretical $(\sin)^2$ curve, as shown in Fig. 3.

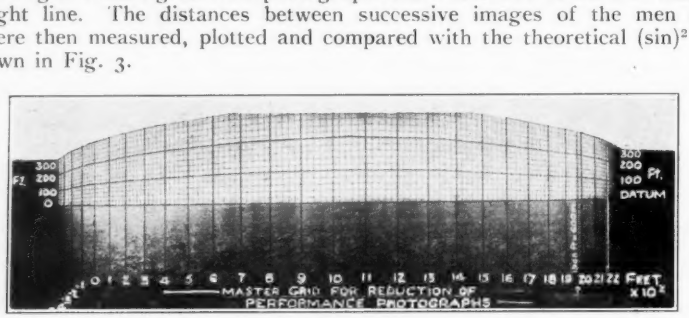



FIG. 3a.

*The Master Grid.*

*In practice it is a transparent print and is superimposed on the actual take-off negative, the correct position being obtained by matching up the horizon irregularities.*

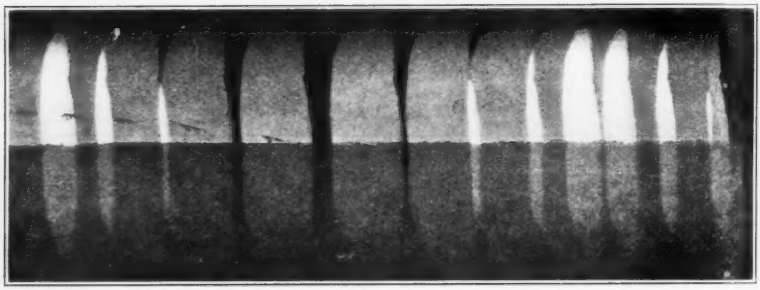


FIG. 3b.

*Typical take-off photograph.*

*This is actually a print whereas the original negative is used for obtaining measurements of co-ordinates with the Master Grid. Twelve images of the machine can be seen and the dark strips are unexposed portions between elementary exposures. The light strips at the ends are doubly exposed portions.*

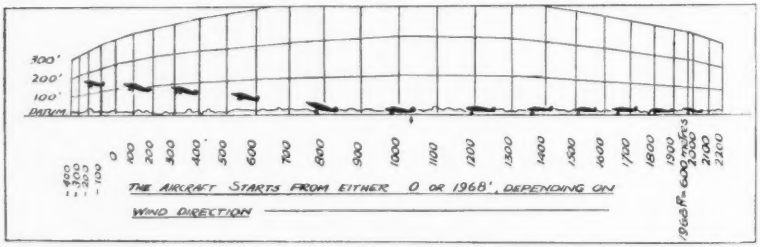
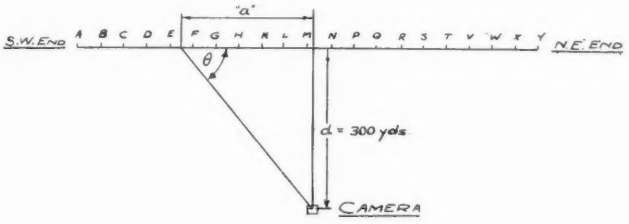



FIG. 3c.

*Diagrammatic sketch of grid superimposed on the take-off photograph of Fig. 3b.*

From the photograph of the signals at 100ft. intervals, verticals can be drawn through these equi-distant points along the desired line of flight and a horizontal datum line may be drawn, having ascertained the relative levels of the two ends by means of normal survey. The horizontal distances on the film representing 100ft. were then multiplied by the appropriate value of cosec $\theta$ to give the




FROM COLUMN 2, $f/d = \frac{0.545}{100 \times 12} = 10^{-4} \times 4.54$

| SEGMENT | DISTANCE OF FILM REPRESENTING (ds) 100ft. | "a" | $\sqrt{a^2 + d^2}$ | | VERTICAL DIST ON FILM TO SAME HEIGHT dH = ds cos θ | THEORETICAL dH = 100 f cosec θ | THEORETICAL ds = 100 f cosec θ | $a^2$ | $(a^2 + d^2)$ |
|---|---|---|---|---|---|---|---|---|---|
| | INCHES | FEET | | | INCHES | INCHES | INCHES | ×10⁻⁴ | |
| AB | 0·24 | 980 | 1330 | 1·48 | 0·361 | 0·370 | 0·248 | 96·3 | 177·3 |
| BC | 0·28 | 880 | 1220 | 1·36 | 0·381 | 0·402 | 0·294 | 77·8 | 158·8 |
| CD | 0·31 | 780 | 1190 | 1·32 | 0·409 | 0·414 | 0·312 | 60·9 | 141·9 |
| DE | 0·35 | 680 | 1128 | 1·25 | 0·437 | 0·437 | 0·348 | 46·3 | 127·3 |
| EF | 0·39 | 580 | 1072 | 1·19 | 0·464 | 0·459 | 0·383 | 33·7 | 114·7 |
| FG | 0·42 | 480 | 1020 | 1·13 | 0·475 | 0·484 | 0·427 | 23·0 | 104·0 |
| GH | 0·46 | 380 | 976 | 1·09 | 0·506 | 0·501 | 0·459 | 14·5 | 95·5 |
| HK | 0·49 | 280 | 943 | 1·05 | 0·520 | 0·520 | 0·494 | 7·85 | 88·8 |
| KL | 0·51 | 180 | 916 | 1·02 | 0·525 | 0·535 | 0·522 | 3·24 | 84·2 |
| LM | 0·54 | 80 | 902 | 1·002 | 0·541 | 0·545 | 0·540 | 0·64 | 81·6 |
| MN | 0·54 | 20 | 902 | 1·002 | 0·546 | 0·546 | 0·540 | 0·40 | 81·4 |
| NP | 0·53 | 120 | 906 | 1·01 | 0·540 | 0·541 | 0·534 | 1·44 | 82·4 |
| PQ | 0·50 | 220 | 926 | 1·03 | 0·520 | 0·531 | 0·512 | 4·84 | 85·8 |
| QR | 0·48 | 320 | 955 | 1·06 | 0·509 | 0·516 | 0·484 | 10·24 | 91·2 |
| RS | 0·44 | 420 | 992 | 1·10 | 0·484 | 0·497 | 0·449 | 17·65 | 98·6 |
| ST | 0·40 | 520 | 1039 | 1·15 | 0·465 | 0·475 | 0·412 | 27·0 | 108·0 |
| TV | 0·36 | 620 | 1092 | 1·21 | 0·434 | 0·451 | 0·368 | 38·4 | 119·4 |
| VW | 0·32 | 720 | 1152 | 1·28 | 0·410 | 0·427 | 0·332 | 51·8 | 132·8 |
| WX | 0·30 | 820 | 1220 | 1·36 | 0·408 | 0·402 | 0·293 | 67·3 | 148·3 |
| XY | 0·27 | 904 | 1277 | 1·42 | 0·386 | 0·385 | 0·270 | 81·9 | 162·9 |

TABLE I.

vertical scale as shown in Table I. The grid of 100ft. squares can now be drawn and then subdivided into an appropriate number of smaller divisions, in this case into 20ft. squares. Actually this division should be done on a tapering scale, but for our prototype layout this refinement was not warranted and each

100ft. was divided into five equal portions. The error thus introduced was small and only affected the horizontal scale as the vertical scale is unaffected by height above the ground.

It is convenient to draw the grid by scratching the emulsion on the panoramic negative of the signals at 100ft. intervals. For ease in matching up with future take-off negatives it is convenient to take a print from the grid so drawn, this print taken on another film or plate, thus giving a transparent positive of the horizon and sky which renders orientation of take-off negatives far more simple.

The Master Grid, as constructed for the prototype camera, is shown in Fig. 3a and the 600 metres distance between the start of run and screen lies between 0 and 1,968 feet, but the grid is continued either way to give points past the screen, whichever direction the take-off may be made.

It will be evident that the calculation of the grid must be done for each change of constants in any apparatus, namely, distance of the camera from take-off run, focal length of the lens and position of the camera relative to the ends of the take-off run. But with a standard camera, camera position, and take-off run, once this initial work of constructing the grid has been completed no further trouble should be experienced and the subsequent time saved will well repay the initial outlay.

## 7. Error in Apparent Height at Screen Due to Machine Deviating from its True Course.

Referring to Fig. 4, in which the machine under test is represented as flying off its course on the camera side of the true line of flight.

Let $\psi$ be the angle between the theoretical and actual lines of flight.
,, $\epsilon$ be the error in the apparent height of the machine at the screen.
,, $\phi$ be the angle of climb of the machine.
,, $\alpha$ be the angle of elevation of the machine from the camera when aircraft is apparently at the screen.
,, $\theta$ be the angle between $OK$ and $OB$.
,, $O$ be the position of the camera.
,, $KB$ be the distance of the camera from the screen measured along the flight path ($KB = X$).
,, $BF$ be the apparent height of the machine at screen ($BF = h$).
,, $OK$ be the distance of the camera from the theoretical line of flight ($OK = l$).
And let $BD$ be the distance the machine is off its true course at the screen ($BD = l$).

Owing to the machine flying in a direction $AD$ and not $AB$ it appears to the camera to be at $F$ (*i.e.*, at the screen) when in reality it is at $G$ which is nearer the start of the run by a distance $CD$ than its apparent position. Had the machine flown this extra length $CD$ it would have risen a height $CD \tan \phi$. This error then makes the machine appear lower than it should be (hence this contributory error is negative and corresponding correction is positive).

Again, due to the machine being at $G$ whilst appearing to be at $F$, it appears higher than it really is by an amount $EF$. (Hence, this contributory error is positive and corresponding correction is negative.)

Combining these two errors, the total error, $\epsilon$, is obtained and is given by

$$\begin{aligned}\epsilon &= EF - CD \tan \phi \\ &= GE \tan \alpha - CD \tan \phi \\ &= CD \operatorname{cosec} \theta \tan \alpha - CD \tan \phi \\ &= AB \tan \psi \tan \theta \,(\operatorname{cosec} \theta \tan \alpha - \tan \phi) \text{ (approx.)}\end{aligned}$$

or

$$\epsilon = AB \tan \psi \,(\sec \theta \tan \alpha - \tan \theta \tan \phi) \quad . \quad . \quad . \quad . \quad \text{(iv)}$$

and this error is zero if we have

$$\sec \theta \tan \alpha - \tan \theta \tan \phi = 0$$

or

$$\tan \alpha = \sin \theta \tan \phi \quad . \quad . \quad . \quad . \quad . \quad \text{(v)}$$

And this means that if the conditions of equation (v) are existing then the machine may fly right off its course without altering its apparent height at screen from the true value.

The expression given in (iv) is for the machine deviating from its true course on the camera side. Should it fly off its course on the other side then the sign of the error changes, but the magnitude remains the same.

The theoretical expression for the error in height at screen (iv) can be reduced to a practical correction chart, the construction of which is outlined below.

It may be noted that throughout corrections are to be added to give the right value and errors are to be subtracted, or they are equal in magnitude, but always opposite in sign.

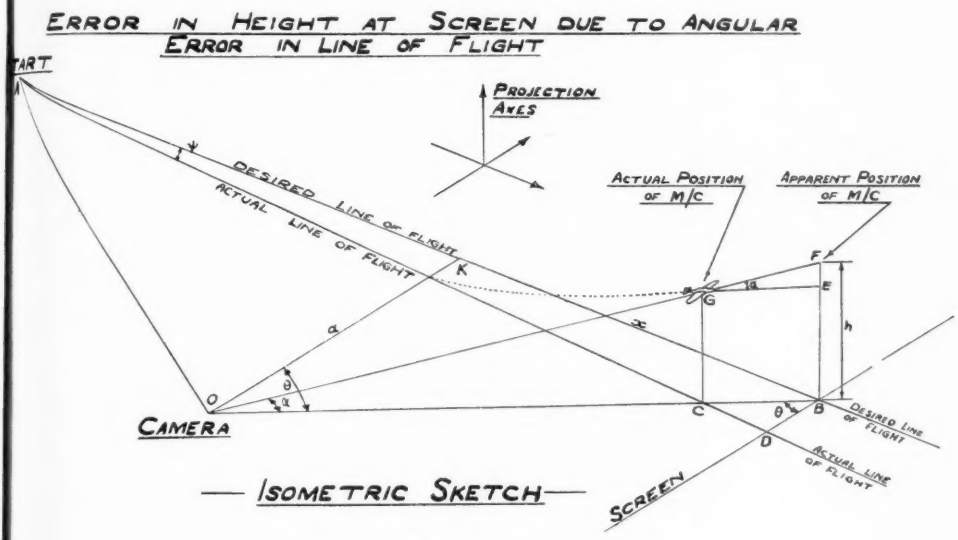

ERROR IN HEIGHT AT SCREEN DUE TO ANGULAR ERROR IN LINE OF FLIGHT
PROJECTION AXES
ACTUAL POSITION OF M/C
APPARENT POSITION OF M/C
DESIRED LINE OF FLIGHT
ACTUAL LINE OF FLIGHT
CAMERA
SCREEN
— ISOMETRIC SKETCH —

FIG. 4.

8. CORRECTION CHART FOR HEIGHT AT SCREEN.

With the same notation as above and referring to Fig. 4,

$$\begin{aligned} h &= OB \tan \alpha \\ &= KB \operatorname{cosec} \theta \tan \alpha \\ &= x \operatorname{cosec} \theta \tan \alpha \end{aligned}$$

or

$$\tan \alpha = h / x \sin \theta \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(vi)}$$

also

$$\tan \theta = x/d \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(vii)}$$

From (iv) we have, using (vi) and (vii)

$$\begin{aligned} \epsilon &= AB \tan \psi \, (\sec \theta \tan \alpha - \tan \theta \tan \phi) \\ &= AB \tan \psi \, \{ \sec \theta \, (h/x) \sin \theta - \tan \theta \tan \phi \} \\ &= AB \tan \psi \, \{ (h/x) \tan \theta - \tan \theta \tan \phi \} \\ &= AB \tan \psi \, \{ h/d - (x/d) \tan \phi \} \\ &= (AB/d) \tan \psi \, (h - x \tan \phi). \end{aligned}$$

And if the machine is off its course an amount " $l$ " at the screen,

$$\tan \psi = l/AB$$

and thus

$$\epsilon = AB/d \,.\, l/AB\ (h - x \tan \phi)$$
$$= l/d\ (h - x \tan \phi) \qquad \text{(viii)}$$

And it is this expression which is represented in the correction chart for height at screen, given in Fig. 6 for the conditions occurring with the present apparatus. For the prototype layout, the camera was placed midway between the start and screen and offset 300 yards from the line of flight. The screen distance was 600 metres or 1,968ft.

Thus

$$x = 984\text{ft.}$$
$$d = 900\text{ft.}$$

and hence

$$\epsilon = l/900\ (h - 984 \tan \phi).$$

Let

$$k = h - 984 \tan \phi \qquad \text{(ix)}$$

and then

$$\epsilon = k \,.\, l/900 \qquad \text{(x)}$$

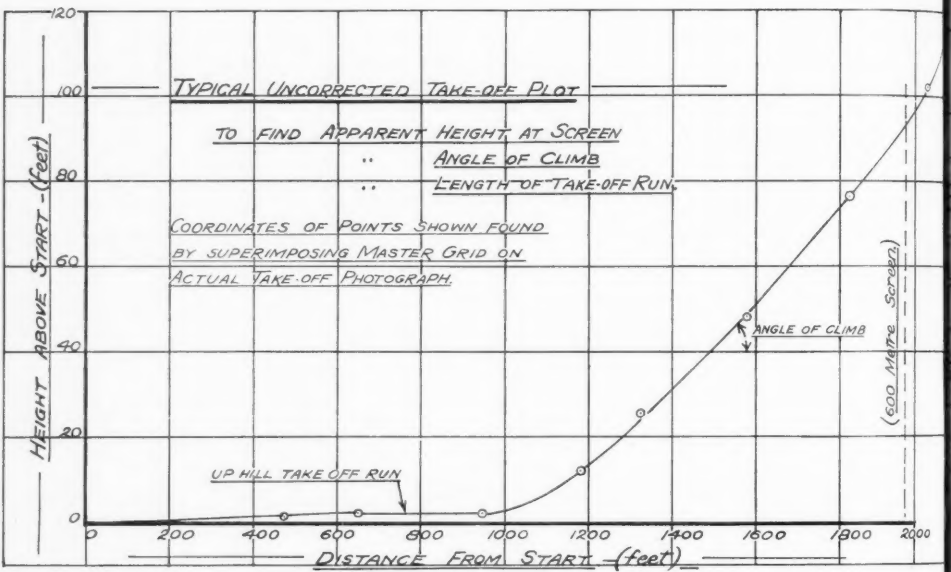



FIG. 5.

Referring to Fig. 6, which is the chart for the prototype layout, the right hand side represents a series of parallel lines given by equation (ix) with varying values of tan $\phi$, or climb, of the machine. The diverging lines on the left of the chart then represent equation (x) with different values of " $l$ " as shown. The use of this chart is then simple, the data required being the apparent height at screen, the angle of climb of the machine, and the distance the machine was off centre at the screen. The first two are obtained from the straight plot of the aircraft's co-ordinates found directly from the take-off photograph and Master Grid. A typical plot is given in Fig. 5 and " $h$ " and " $\phi$ " are directly obtainable. The third item is obtained from an observer behind the machine who can accurately measure the aircraft's eccentricity by means of stakes in the ground at the screen.

To find the correction, start from the apparent height of the machine at the screen (Fig. 6) and move vertically until the diagonal line representing the appropriate angle of climb is reached. From this point move horizontally to meet the line representing the appropriate eccentricity of the machine at the screen. From here move vertically to obtain the correction.

It will be noted that the angle of climb of the machine as found from the plot of Fig. 5 is only approximate if the aircraft is not flying along its true course, but the error thus introduced is well below the accuracy of the method as a whole and can quite properly be neglected in the present case. However, it is a possible refinement should greater accuracy be required and more accurate apparatus be used. As has been stated above, the accuracy of the prototype apparatus was ±2 feet and was governed by the accuracy of construction of the Master Grid.

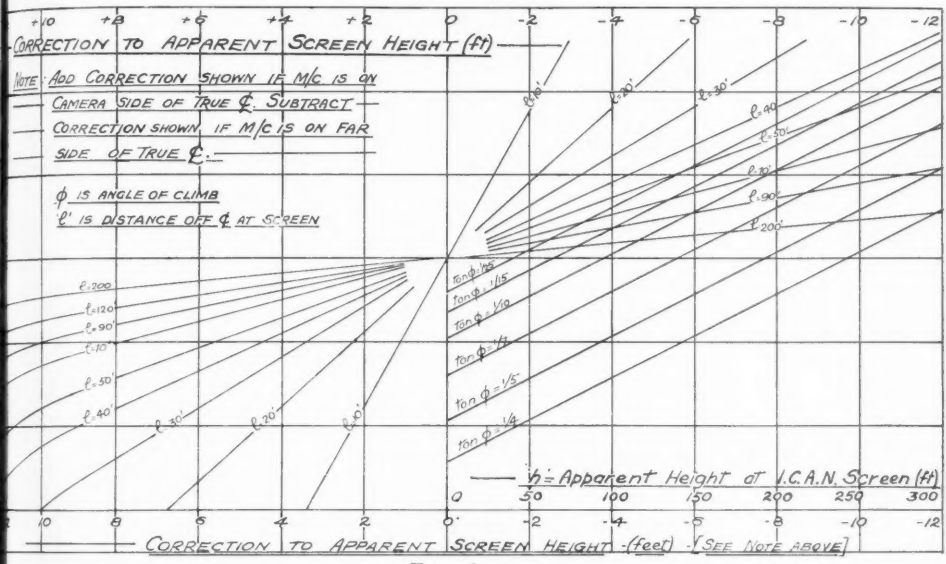

CORRECTION TO APPARENT SCREEN HEIGHT (ft)
NOTE: ADD CORRECTION SHOWN IF M/C IS ON CAMERA SIDE OF TRUE ℄. SUBTRACT CORRECTION SHOWN IF M/C IS ON FAR SIDE OF TRUE ℄.
φ IS ANGLE OF CLIMB
℄' IS DISTANCE OFF ℄ AT SCREEN
h = Apparent Height at I.C.A.N. Screen (ft)
CORRECTION TO APPARENT SCREEN HEIGHT (feet) [SEE NOTE ABOVE]

FIG. 6.

*Correction chart for apparent height at screen.*
*The apparent height at screen and angle of climb are found from a plot similar to Fig. 5. The distance the machine was off centre at the screen is reported by an observer. Start from apparent height at screen, move vertically to meet angle of climb line, thence horizontally to meet line representing amount off centre, thence vertically to find correction, due regard being taken of sign. The above chart was for the prototype layout.*

It will also be noted that a different correction chart will be required for each change in the distance of the screen from the start of the run or for any change in the geometrical layout of take-off run and camera.

The method can be easily modified to cater for landings, in which case a distinct landing line will be needed of sufficient clearness to allow accurate approaching.

9. ERROR IN APPARENT TAKE-OFF RUN DUE TO AIRCRAFT BEING OFF ITS TRUE COURSE.

This is most easily found graphically by drawing a plan of the layout and measuring the apparent and actual lengths from the start for different angular

errors in the line of flight of the machine. Fig. 7 shows the present layout and angular deviations of $1\frac{1}{2}°$, 3° and 5° on the side of the true line near the camera are represented.

Remembering that the grid for obtaining co-ordinates of the aircraft's position in the photographs is virtually positioned along the desired line of flight, it is a simple matter to measure the apparent and actual distances from the start and thus to obtain curves such as shown in Fig. 8. It will be seen from these curves that for take-off runs of the normal order, the distance from the start of the run is not affected greatly by angular deviation of the aircraft, but what error there is may be quickly corrected by the curves which must be constructed for each geometrical layout of camera and take-off run.

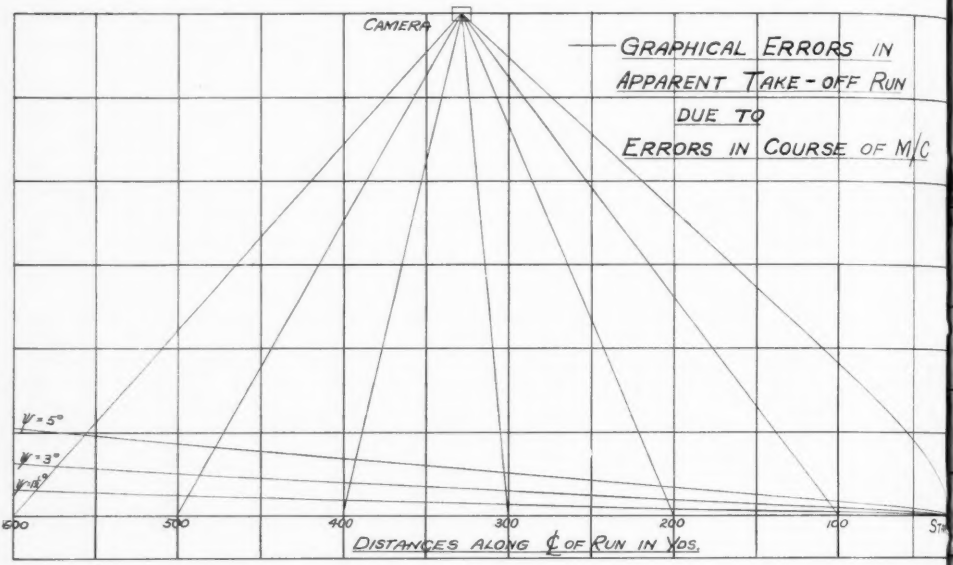



FIG. 7.

10. ERROR IN THE APPARENT RATE OF CLIMB DUE TO ANGULAR DEVIATION OF AIRCRAFT.

This also is most easily found graphically with a plan sketch such as Fig. 7, and the result is most conveniently given as a factor by which the apparent rate of climb is to be multiplied to give the correct value.

It will be evident that if the aircraft is closer to the camera than it should be, then it will appear to be rising more quickly than it actually is and hence the correction factor will be less than unity. Similarly, if machine is too far away, the correction factor will be greater than unity. The actual value of the factor will be the ratio of the actual distance of the aircraft from the camera to the distance it would be if it were at the desired line of flight. This, then, can be readily obtained from a sketch such as Fig. 7, and for the present prototype layout the correction factors are given in Fig. 9 for certain angular deviations.

11. VELOCITY AND ACCELERATION DETERMINATIONS.

This may be carried out conveniently by logarithmic plotting of the distance from the start of run and corresponding time. Let these be denoted by "$s$" and "$t$" respectively.

From the photograph of the take-off is obtained a series of images of the aircraft, each of which has been obtained at a known time from the start. The

co-ordinates of these images are directly obtainable using the Master Grid, and the observer behind the aircraft can give the angular deviation. From this the apparent distances from the start can be corrected using a curve of the nature of Fig. 8, thus giving the true distances from the start at known times.

By plotting the time and corresponding distance from the start logarithmically a straight line relationship has been found to hold in every case and a typical plot is shown in Fig. 10. This straight line relationship on the logarithmic plot allows an expression to be obtained relating " $s$ " and " $t$," of the form

$$s = a \cdot t^x$$

where $a$ is a coefficient and $x$ is a numerical index.

Hence

$$V = ds/dt = a \cdot x \cdot t^{(x-1)}$$

giving the velocity at time " $t$ " from the start, and

$$f = d^2s/dt^2 = a \cdot x\,(x-1)\,t^{(x-2)}$$

giving the acceleration at time " $t$ " from the start.

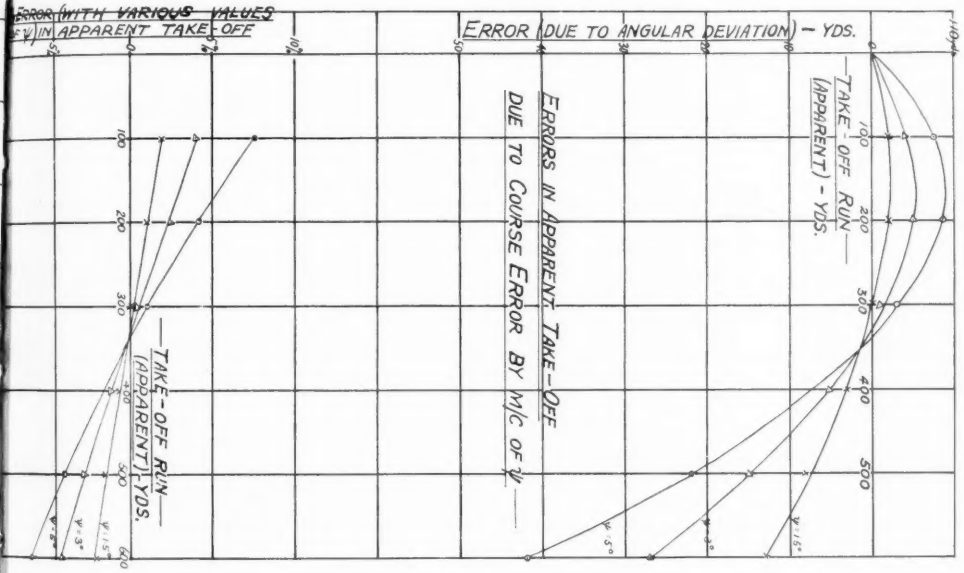

ERROR (WITH VARIOUS VALUES OF ψ) IN APPARENT TAKE-OFF
ERROR (DUE TO ANGULAR DEVIATION) - YDS.
ERRORS IN APPARENT TAKE-OFF DUE TO COURSE ERROR BY M/C OF ψ
— TAKE-OFF RUN — (APPARENT) - YDS.
— TAKE-OFF RUN — (APPARENT) - YDS.
ψ = 5°
ψ = 3°
ψ = 1·5°

FIG. 8.

The progress of the aircraft might more accurately be represented by two straight lines on the logarithmic plot, one covering the early stages and one the subsequent movement. However, one line has been sufficient up to the present, as shown by the plot of Fig. 10, which is an actual case and is quite typical. It will be noted that this logarithmic plot gives only an approximation and the expression for acceleration is not exact after the machine starts to climb at constant speed when the acceleration becomes zero. But up to this point the approximation is close.

Another method of obtaining velocity and acceleration values is by direct deduction from the co-ordinates of the aircraft obtained from the take-off photograph and master grid. Knowing $s_1$ and $s_2$, the distances from the start at $t_1$ and $t_2$ seconds, the mean velocity over the period is $(s_2 - s_1)/(t_2 - t_1)$. Similarly

the mean acceleration over the interval is $(v_2-v_1)/(t_2-t_1)$ where $v_1$ and $v_2$ are the velocities at the start and finish of the period respectively.

12. Film Shrinkage.

The length of a strip of film varies quite considerably with humidity and the result is that it is possible to cause $\frac{1}{8}$in. variation in a 10in. strip by alternating extreme conditions.

As the present method uses film, and the horizon irregularities of take-off photograph and Master Grid have to be made to correspond, it will be seen that this latter operation will be rendered difficult if the two films have been under different atmospheric conditions previously. Should one shrink and not the other it will only be possible to match horizon irregularities at one portion at a time—at that portion of the photograph where the co-ordinates of a certain image are required.

But if the treatment of the film is careful and the take-off negatives are properly dried, little difficulty will be experienced from this and the difference in length between two corresponding points on the horizon should not exceed $\frac{1}{32}$in. at the most on a 12in. gauge length.

It seems reasonable that the film will shrink approximately equally longitudinally and transversely, length for length, and thus the error induced in the height of the machine will be below the accuracy of the method and can be neglected.

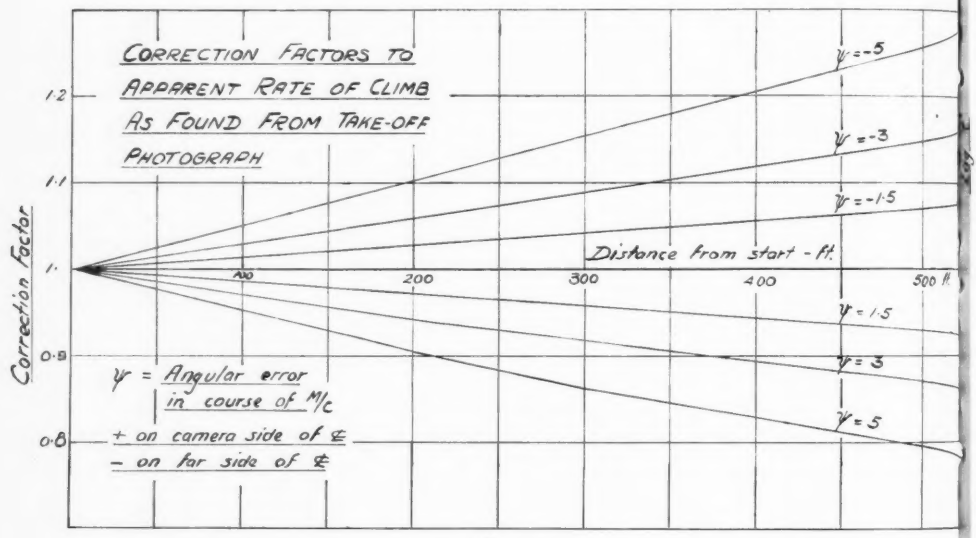



Fig. 9.

13. Reduction of Co-ordinates from Photograph.

The reading of the co-ordinates of the aircraft under test is facilitated if each image of the machine on the take-off negative is first pin pricked at some corresponding point, *e.g.*, spinner, bottom of undercarriage wheel, etc., due regard being taken of the wheels retracting or the relative heights of the spinner and C.G. of the machine altering as the aircraft leaves the ground and climbs.

14. General Notes.

It is confidently thought that this method for measuring the performance of aircraft through a most important stage should give little trouble in practice.

The prototype camera, constructed at very small cost and consisting of the bare essentials only, has been performing consistently during the last ten months and has given the required results under all conditions of weather and lighting.

Besides giving a permanent record of a machine's performance, the small field staff needed for operation is a strong point. It means that performance measurements of take-off may be carried out with a minimum of inconvenience and waste of time and the results obtained can be filed for reference and data can be extracted as desired.

In the above notes more stress has been laid on the use of the method for measurement of take-off than for measurement of landings, but it is evident that the method can be used for either.

Nor are these notes meant to be more than a general outline of what is thought to be a new and very simple method of obtaining rather important and useful results.

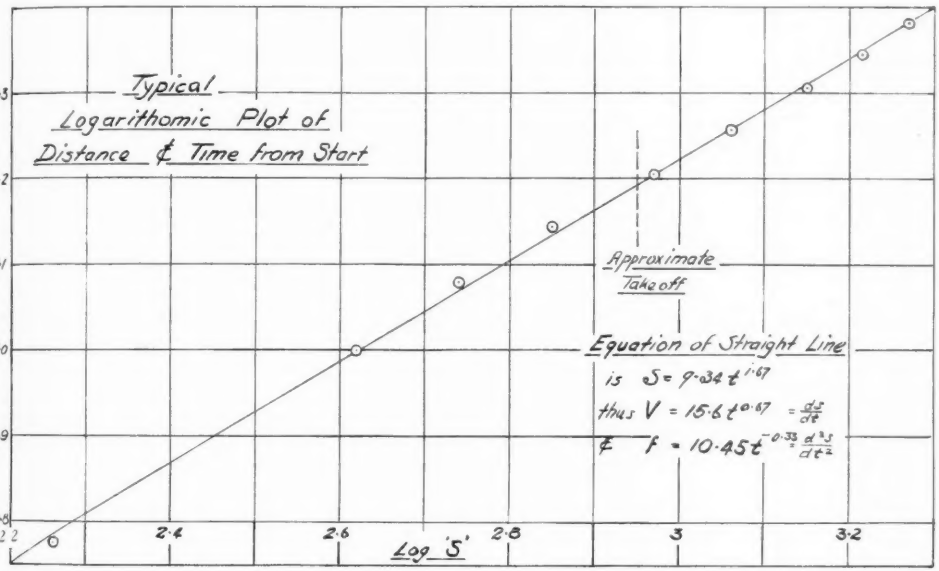



FIG. 10.

MEASUREMENT OF WIND VELOCITY GRADIENT.

An investigation which has a definite bearing on take-off and landing performance is now being carried out using this camera to determine the wind velocity gradient on the aerodrome under consideration for different conditions.

This is done by releasing hydrogen balloons on the centre line of the take-off run with the wind in the right direction, and then photographing the resultant motion at regular intervals as for a normal take-off or landing. In fact, one is merely photographing a balloon taking-off instead of a machine.

The horizontal distance travelled between successive regular exposures gives the wind velocity at that height, and as the balloon goes up so the velocity further up is obtained. Thus, it is an easy matter to get the velocity gradient and to correlate it with the normal anemometer readings obtained near the ground.

This investigation is as yet incomplete, but is mentioned as an interesting application of the camera.

the mean acceleration over the interval is $(v_2-v_1)/(t_2-t_1)$ where $v_1$ and $v_2$ are the velocities at the start and finish of the period respectively.

12. Film Shrinkage.

The length of a strip of film varies quite considerably with humidity and the result is that it is possible to cause $\frac{1}{8}$in. variation in a 10in. strip by alternating extreme conditions.

As the present method uses film, and the horizon irregularities of take-off photograph and Master Grid have to be made to correspond, it will be seen that this latter operation will be rendered difficult if the two films have been under different atmospheric conditions previously. Should one shrink and not the other it will only be possible to match horizon irregularities at one portion at a time—at that portion of the photograph where the co-ordinates of a certain image are required.

But if the treatment of the film is careful and the take-off negatives are properly dried, little difficulty will be experienced from this and the difference in length between two corresponding points on the horizon should not exceed $\frac{1}{32}$in. at the most on a 12in. gauge length.

It seems reasonable that the film will shrink approximately equally longitudinally and transversely, length for length, and thus the error induced in the height of the machine will be below the accuracy of the method and can be neglected.

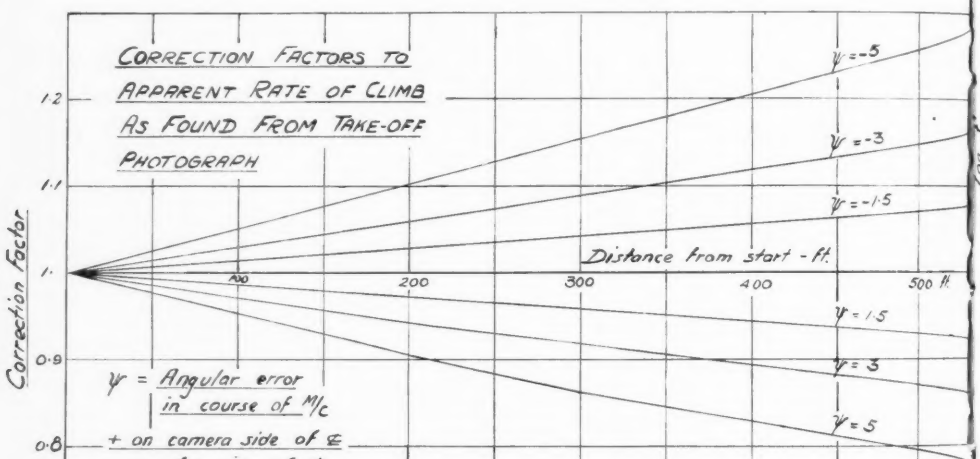



Fig. 9.

13. Reduction of Co-ordinates from Photograph.

The reading of the co-ordinates of the aircraft under test is facilitated if each image of the machine on the take-off negative is first pin pricked at some corresponding point, *e.g.*, spinner, bottom of undercarriage wheel, etc., due regard being taken of the wheels retracting or the relative heights of the spinner and C.G. of the machine altering as the aircraft leaves the ground and climbs.

14. General Notes.

It is confidently thought that this method for measuring the performance of aircraft through a most important stage should give little trouble in practice.

The prototype camera, constructed at very small cost and consisting of the bare essentials only, has been performing consistently during the last ten months and has given the required results under all conditions of weather and lighting.

Besides giving a permanent record of a machine's performance, the small field staff needed for operation is a strong point. It means that performance measurements of take-off may be carried out with a minimum of inconvenience and waste of time and the results obtained can be filed for reference and data can be extracted as desired.

In the above notes more stress has been laid on the use of the method for measurement of take-off than for measurement of landings, but it is evident that the method can be used for either.

Nor are these notes meant to be more than a general outline of what is thought to be a new and very simple method of obtaining rather important and useful results.

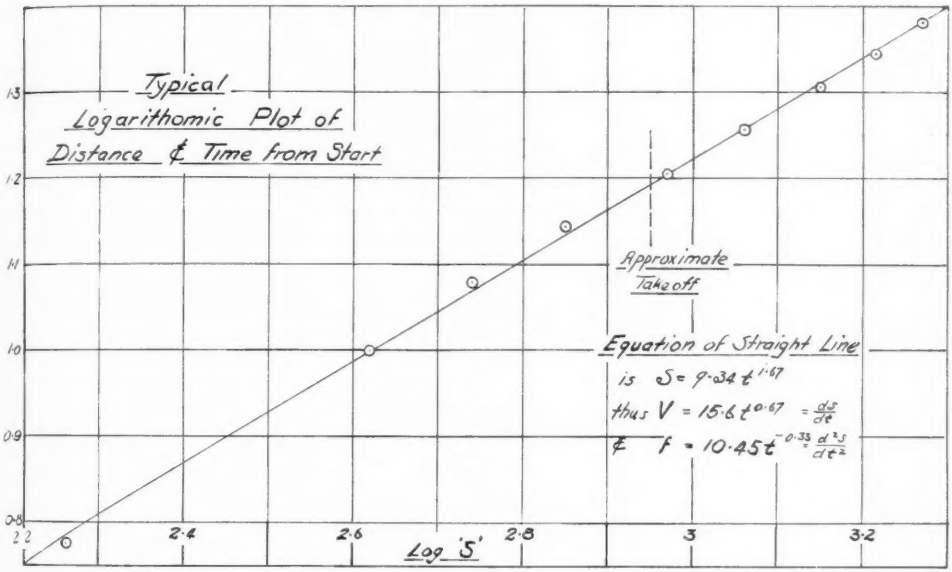



FIG. 10.

MEASUREMENT OF WIND VELOCITY GRADIENT.

An investigation which has a definite bearing on take-off and landing performance is now being carried out using this camera to determine the wind velocity gradient on the aerodrome under consideration for different conditions.

This is done by releasing hydrogen balloons on the centre line of the take-off run with the wind in the right direction, and then photographing the resultant motion at regular intervals as for a normal take-off or landing. In fact, one is merely photographing a balloon taking-off instead of a machine.

The horizontal distance travelled between successive regular exposures gives the wind velocity at that height, and as the balloon goes up so the velocity further up is obtained. Thus, it is an easy matter to get the velocity gradient and to correlate it with the normal anemometer readings obtained near the ground.

This investigation is as yet incomplete, but is mentioned as an interesting application of the camera.

## Conclusion.

In conclusion the authors wish to thank the de Havilland Aircraft Co. for permission to publish these notes, and Mr. R. M. Clarkson, in charge of the Aerodynamics Department of the same company, for his advice and help throughout the development.

Also they wish to acknowledge the assistance of Dr. O. M. Ede, Mr. W. Isbister and Mr. K. E. Wholley for reading the proofs and preparing the drawings.

# THE WING-BEAT OF PIGEONS.

By G. Guidi.

(*Translated from the Italian: "La Battuta Alare del Piccione"—AEROTECNICA February, 1939, by Frances Buss*).

*Résumé*—After some general remarks upon the constant flight characteristics of birds belonging to any given species, the author describes his method of obtaining, approximately, a cinematographic reproduction of three geometrical projections of the wing-beat. Dealing with one particular case he determines the trajectory in space of a pigeon's wing tip during an entire beat, and, also, the speed and acceleration reached by it.

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To define the shape and size of any object in space, three complementary projections of it are needed. The representation of a moving body in space is also subject to this fundamental law of three-dimensional geometry, if one desires to reconstruct the shape and position of the object in question at any one moment; or again at several moments, which may be equidistant in time if a succession of images are required for the purpose of studying the laws of movement.

If the object is in motion, obviously the three projections of it in each successive position must be simultaneous.

These premises are essential both for determining the positions of birds in flight and for studying their motion, and it is the difficulty in obtaining three projections which has hitherto prevented investigators from obtaining satisfactory results.

This necessity was perfectly recognised in the past and was pointed out by Marey as early as 1890. He proposed to solve the difficulty by using an apparatus of his own, consisting of three cameras with complementary axes, electrically synchronised, trained upon three dark background screens, against which he expected the figure of the bird to show up clearly. Actually, however, although half a century has now passed, during which experimenters might easily have solved those difficulties of synchronisation and illumination which at that time were unsurmountable, no practical result has been obtained by these means.

Magnan has recently achieved striking results in another direction. He has obtained three simultaneous projections, one image being photographed directly on to the film and the other two being reflected in mirrors arranged so as to give the images corresponding to two complementary optic axes at right angles to each other and to the first optic axis. I think that, from a strictly scientific point of view, Magnan's results with this apparatus are the best which could have been obtained.

However, even Magnan's solution does not appear complete and exhaustive, principally for the following reasons: firstly, the impossibility of covering a sufficiently wide field and of following the bird on the wing mean that it is photographed not in full flight but only during one or two initial wing-beats, starting from rest. These wing-beats, in the duration of each successive phase, in the amplitude of the wing movements, and in the position of body and tail, vary distinctly from those which correspond to normal horizontal or climbing flight. Secondly, the need to crowd the three pictures on a single photogram, necessarily of limited dimensions, entails making very small images which, although quite clear, do not show sufficient detail for a complete analysis of the different parts of the body and the wings. Finally, the need to make the bird fly off at a definite instant

renders it necessary to stimulate it by some external means—in the case under consideration by an electric current—which in all probability affects the normality of its movements, at least during the initial wing-beats until the nervous shock has abated.

In this connection I would say that even in full flight it often happens that a wing-beat is not synchronised, or is weaker than that of the other wing, or there are individual movements of the tail or head; such abnormalities last for one or two wing-beats, and it would be absolutely wrong to generalise them as occurring in normal flight.

I will pass over other difficulties— of illumination, for example—inherent in this system, and will merely conclude that, although I consider Magnan's results most remarkable and perhaps unsurpassed from a scientific point of view, they do not appear to me to constitute a complete study of beating-wing motion in normal flight.

In both systems great difficulties arise, because it is impossible to fix and control the flight-path of the bird, which is extremely variable and arbitrary. Besides, as always happens when photographing birds in flight, if the subject is near the lens the angular displacements are so large that it is impossible to follow it long enough; if far away, it is easier to keep the subject centred, but its image is so small and lacking in detail that all possibility of studying relative movements is lost. I am, of course, using the term " distance " in the relative sense of the focal distance of the lens. The use of telescopic lenses not only does not solve these difficulties, but actually increases them, since the thick layer of air interposed between the camera and its subject absorbs light and causes a great deal of detail to be lost.

So I feel that up till now neither of these two ways—the only ones which are scientifically exact—has led to positive results in photographing birds on the wing.

When it is impossible to solve a problem by strictly scientific methods it is solved by approximation, and the result may be equally good if the degree of approximation is sufficient for the required end, and above all if it can be controlled. And this is the method I have adopted for the researches which I am now going to describe.

As already mentioned in a previous article,* although I have tried to classify pigeon flight into four types, in reality the modalities of flight are infinite, because the transition from one type to another takes place imperceptibly, and because the trajectory itself may be inclined or curved in any direction; hence its characteristics may vary from point to point. Besides, the flight may present different characteristics because of emotional factors affecting the bird: for example, a gun-shot or a sudden bright light will produce a reflex increasing the amplitude and frequency of the wing-beats, whilst far more disorderly and complex movements are induced by an obstacle in the line of flight.

Nevertheless, in spite of this great, and apparently chaotic, variety of positions and movements which winged creatures may assume during flight, it is easy to observe that for one definite species the technique of flight is always the same and is constant. Therefore, given a straight flight-path at a similar angle of incidence and an equal speed, the amplitude, frequency and phase characteristics of the wing-beats are sufficiently constant not only for one particular bird, but for all birds of the same species.

In particular, a pigeon which leaves the ground in straight climbing flight at a given angle of incidence referred to the horizon, after the first few beats settles down to a frequency, amplitude and wing-beat characteristics which may be considered practically constant, so long as the flight-path does not change; the steeper the climb the more frequent are the wing-beats, the downward phase being short in comparison with the total time of each beat; the more nearly horizontal the

* GUIDI: A Study of the Wing-beats of Pigeons in Flight: AEROTECNICA, Aug. 1938, translated in R.Ae.S. Journal, December, 1938.

flight becomes the less frequent are the wing-beats, and the duration of the downward phase lengthens in comparison with the total time of the beat.

Admitting this principle, one arrives at the conclusion that it is no longer essential to take the three complementary projections simultaneously, and that, provided the conditions of the flight-path are kept similar, three photographs may be taken on three different and successive flights, corresponding to the three complementary axes; thereby obtaining three series of corresponding pictures which represent the different moments of the wing-beat.

In other words, by this means, one obtains three series of photograms of one particular bird in three different flights, made under the same conditions. One series shows it in side view, one head on or tail on, and one from above or below. Collating three photograms, one from each series, which represent the bird at a particular point of its stroke, together with the preceding and following photograms in all three series (all taken at the same speed), you have a set corresponding to positions equidistant in time which the bird has assumed during its flight, being the three complementary projections in space of the successive positions assumed by the bird.

In reality the solution is not as simple as it might appear. Having overcome the difficulty of catching a single bird flying in practically identical conditions three times running, there still remains that of obtaining three series of photograms which have a sufficiently good time-overlap, *i.e.*, which actually represent the three projections of identical intermediate wing positions. This difficulty is overcome by high-speed photography, giving such a short interval between one photogram and another that the out-of-phase positions between one series and another are reduced to a minimum. In any case, complete synchronisation can only be obtained by having a very wide field of choice among the three series of films in the three basic directions. Consequently one should not merely have three series, but there should be a sufficient number, in all three directions, to give a convenient field of choice in making up the sets of pictures.

In practice I had several hundreds of cinematographic series of wing-beats, taken at frequencies of 64 and 128 photograms per second, comprising respectively about 9 or 18 photograms for each wing-beat. Among these series it was not difficult to pick out a few sets which represented, with sufficient accuracy for my purpose, the three complementary projections of as many intermediate positions of the wing-beats.

Besides, as these three projections are governed by well-known geometrical laws, it is easy to ascertain whether the three views conform with these laws; if not, one or other of the photographs can be rejected and a substitute chosen. Of course, the scale of the three series of pictures is not always identical, but this can easily be countered by enlarging one or other of the series to the required size. All the pictures are taken close up, holding the camera in the hand, as I described in my previous article.

The series reproduced in the present study is, of course, one of the best, comprising nine photograms for each of the three projections. These were taken at a speed of 64 photograms per second. This number of photograms is sufficient to give a complete picture of the bird's movements, even without having recourse to higher speeds which would simply have given an accumulation of unnecessary pictures. Even an interval of 1/64 second between two successive positions is enough to give a complete determination of the laws of movement.

The last position illustrated does not link up with the first, there being an interval between the two of approximately 1/126 second. The flight is ascending, with an incidence of about 25° from the horizontal. The exposure speed of each photogram is about 1/2000 second.

Any discrepancy in phase between the three sets of pictures reproduced is negligible, as is shown by the almost perfect correspondence of the three projections. In every case differences of phase are so slight that they form no obstacle to the deductions which may be made from this study.

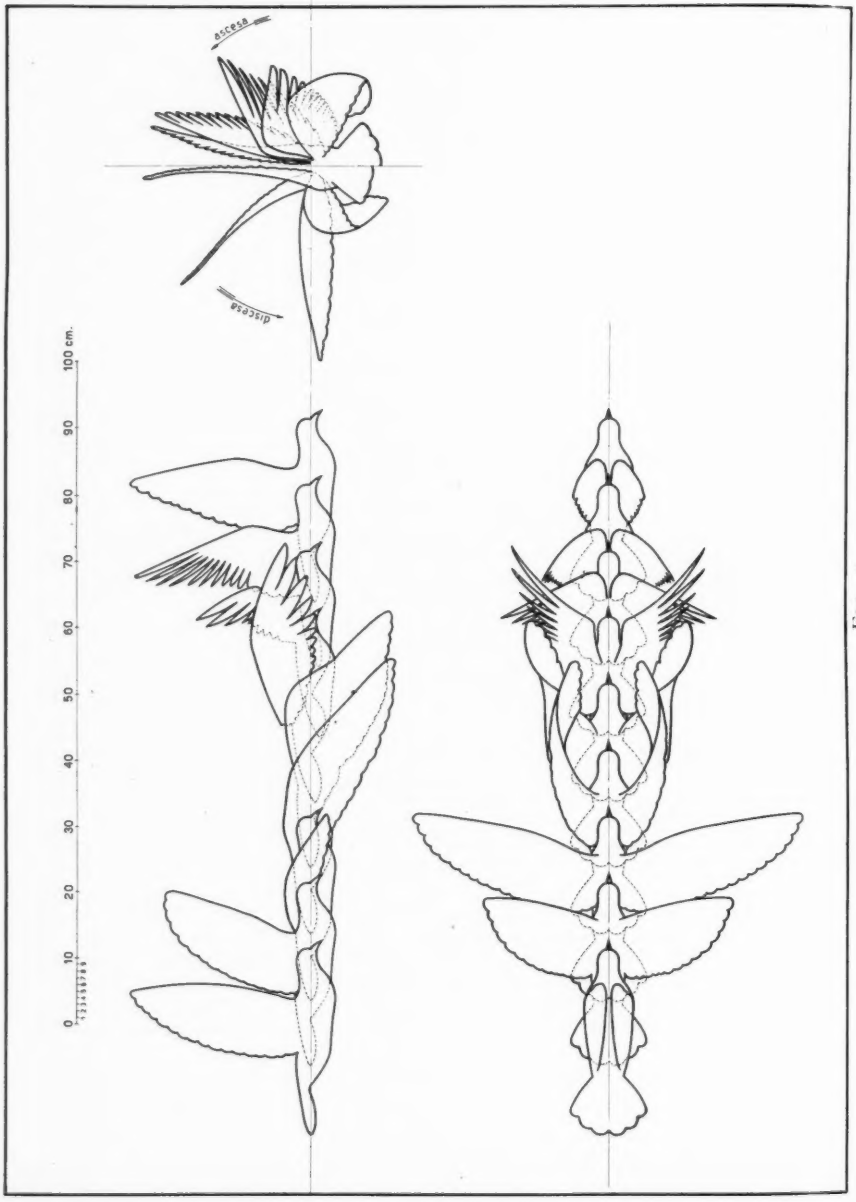



FIG. 1.

*Wing-beat movement and forward movement superimposed, in all three projections.*

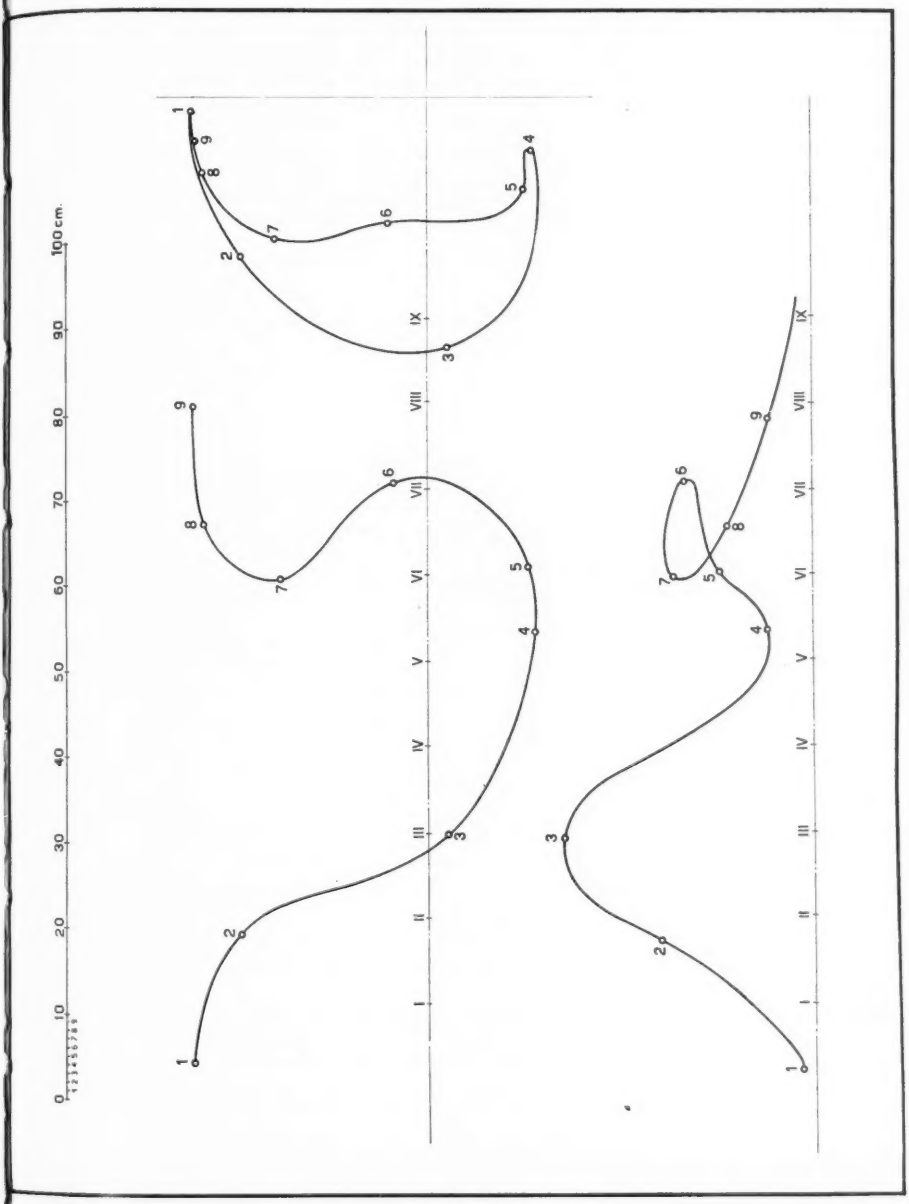



FIG. 2.
*Wing-tip trajectory in all three projections.*

*Wing-beat movement and forward movement superimposed, in all three projections.*

The complexity of the wing movements is evident. In the descending phase the arm, forearm and hand are rigidly in line and rotate around the scapula from the upward position to the downward and forward. Just below the horizontal position the forearm and hand bend still more markedly forward and towards the bird's body, so as to accentuate the forward stretch of the wing. At this point, whilst the hand keeps the same direction, the arm and forearm bend definitely upwards. With this movement the main flight feathers separate one from another, and under aerodynamic pressure turn slightly around their calamus, so as to transform the continuous wing plane into a number of small isolated planes, independent and parallel. When the arms and forearms have assumed an almost vertical position the hands turn around the forearms, remaining in a plane parallel to the lateral axis of the bird, at an angle of about 45° to the longitudinal axis and inclined backwards. In this movement the wing-spread is reduced to about half

*Horizontal longitudinal components (positive in a forward direction).*

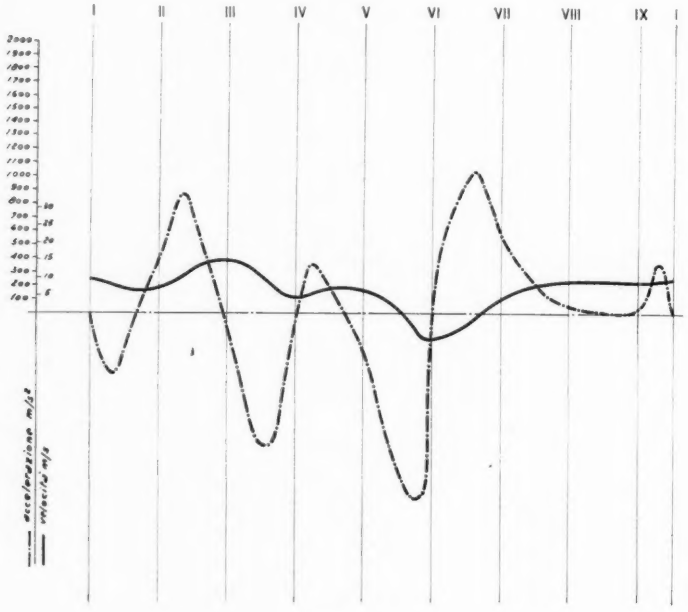



FIG. 3.

*Speed and acceleration components of the wing-tip.*

the total spread in the downward phase; besides this the wing surface is broken up into a number of small planes like the lathes of a Venetian blind. As soon as the hands are in the vertical plane, parallel to the longitudinal axis which contains the arms and forearms, a small forward rotation of the hands brings them into line with the arms, and the wing is ready to start a fresh beat with a new downward phase.

The attitude of the wing and the laws of movement which I have described are very clearly shown in the three series of illustrations reproduced with this article. These have been made by considerably enlarging the bird and isolating it from its background, from corresponding series of photograms, taken, as I have said, at a speed of 64 per second.

Suppressing the background, whilst it makes the image of the bird stand out more clearly, prevents one from appreciating the forward movement of the pigeon, which on the original photograms can be observed and gauged very well.

To get a clear idea of the movement resulting from the wing-beat and the forward speed, turn to Fig. 1, which shows, brought into alignment, the three separate projections of the nine intermediate wing positions. All wing movements are referred to the body of the bird, which is supposed to be moving at a uniform speed in a straight line; in reality the movement is not quite regular and the flight path is slightly curved. However, the simplification introduced does not matter much, given the amplitude of the wing movement—from which the law is studied—in comparison with the sinusoid traced by the centre of gravity.

Such a detailed view of the different parts of the pigeon in the 27 positions illustrated enables one to determine exactly, apart from the movements which I have intentionally neglected, the laws of motion of all its body and wing parts. I have done this in particular for one part which obviously is of special interest—the wing-tip.

It is not easy to construct a graph of the trajectory of the wing-tip and the speed and acceleration recorded along it, because of the complexity of the line in space which represents the flight path, and the continuous angular variation of the vectors of velocity and acceleration. I therefore thought it better to have recourse to a method which, if less obvious than a perspective, is more easily utilised for purposes of calculation; *i.e.*, to represent the trajectory by means of three complementary projections (Fig. 2) and construct diagrams of the velocity and accelerations respectively for the three components of the corresponding vectors—the horizontal longitudinal, the horizontal lateral, and the vertical.

The curve representing the lateral projection of the trajectory has some similarity with the curve shown in Fig. 1 of my previous article. Some difference arises from the fact that in the former case the flight path was at an angle of 45° whilst now it is at 25°, and the corresponding forward speeds are also different. Besides, the former Fig. 1 obviously represents a plotted curve, whereas the present graph is the actual projection of the real trajectory, constructed point by point. Apart from these reasons for divergence in the two drawings, it cannot be denied that the elements I possessed when compiling the former study were much less complete than those which I have now obtained by reconstructing the three complementary projections; the great advantage of the new method is evident from this comparison.

As for the construction of the diagrams of speed and acceleration, I started with the following simplifying hypotheses:—

(1) To substitute for the actual trajectory one split up into straight lines, joining up the points touched by the nine photograms reproduced.

(2) To calculate the three components of the average speed in each of these nine fields and use them as ordinates in the three diagrams corresponding to the three projections of speed.

(3) To construct the three curves of the three projections of speed as graphs.

(4) To divide each of the fields into four sections (except the last, which, being shorter, is divided only into two), so as to obtain points 1/256 second apart and construct from these points the curves of the three components of acceleration, by means of graphical derivation.

A check by analytical methods has shown that the method followed, although not strictly exact, is a sufficiently close approximation.

To give the effective values of the speeds and accelerations (*i.e.*, the values resulting from the collation of the three components on the preceding diagrams) would not clearly indicate the trend of the corresponding functions, because in a cartesian diagram one cannot represent the angular variation together with the algebraic value of the vectors referred to time. So I thought it better to draw up a table giving the total values of speeds and accelerations. From another point

of view these are of great interest, as they constitute the maxima which are reached during the wing-beat.

The high values are striking, since when the pigeon is travelling at a forward speed of only 5.85 metres per second, its wing-tip reaches speeds of about 23 metres per second and accelerations of about 2200 metres per square second. Given the simplifying hypotheses which have been introduced, the maximum acceleration values are probably higher than those indicated.

Such high accelerations would require forces much greater than the bird's muscles could develop, if they were not applied to masses infinitely small, as in fact are those of the feathers and the wing structures in general. One can only admire the skill with which nature reconciles the limitations of the forces available with the necessity of violent movements, by means of the smallness of the masses.

*Horizontal lateral components (positive outwards).*

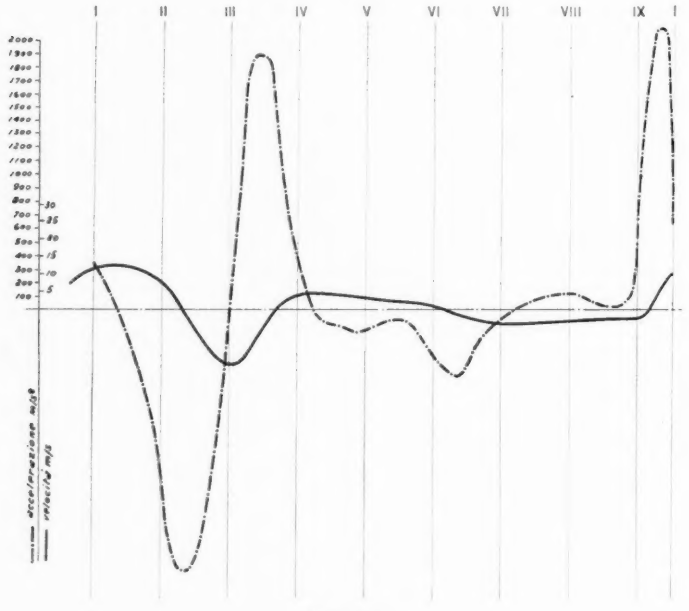



FIG. 4.

*Speed and acceleration components of the wing-tip.*

Any kind of mechanical construction trying to achieve something similar to the natural wing-beat, apart from the enormous difficulties of construction, would introduce disproportionately large masses. The forces would increase proportionately, and with them the stresses in the materials, arriving rapidly at altogether impracticable figures.

Another very important consideration emerges from an examination of the graphs and of the high numerical values of the accelerations: acceleration maxima are found during the downward phase of the beat; as a vector the acceleration is almost perpendicular to the wing surface during the first phase of the downward beat; afterwards it bends forward and almost follows the wing surface in the final period of the descending phase. In the first period, besides an inertia reaction

in the wing, which is limited by the very small mass of the wing itself and of the flight feathers in particular, there exists a mass reaction of the air which is by no means negligible and which is independent of the classical aerodynamic reaction due to circulation. An approximate calculation would appear to show that the two reactions are of about the same strength. Since the two maxima are not coincident, we come to the logical conclusion that the bird develops the force that it wishes to spend, in acceleration and in lift, as the term is generally used.

The forward acceleration during the last period of the downward phase seems due essentially to a component of aerodynamic reaction: in any case it does not

*Vertical components (positive downwards).*

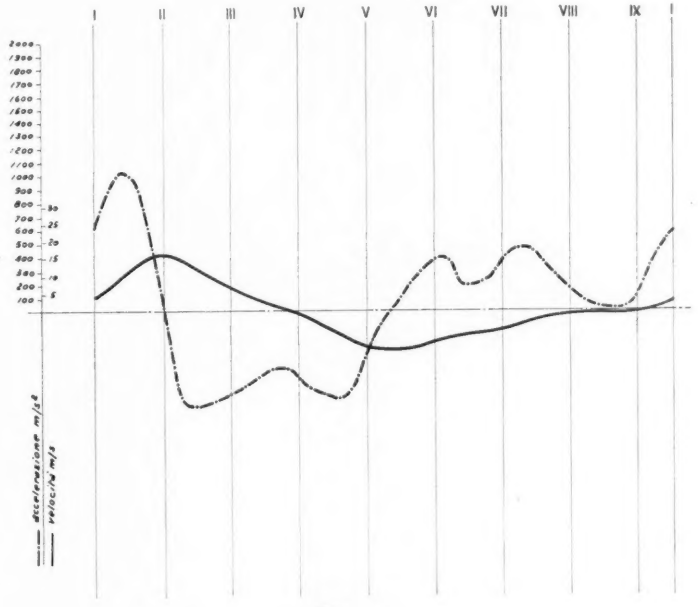


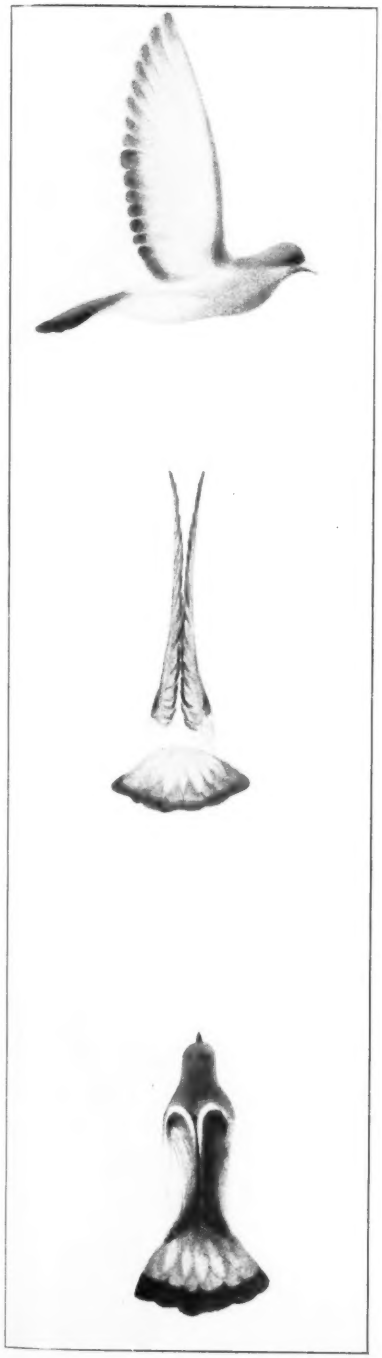

FIG. 5.

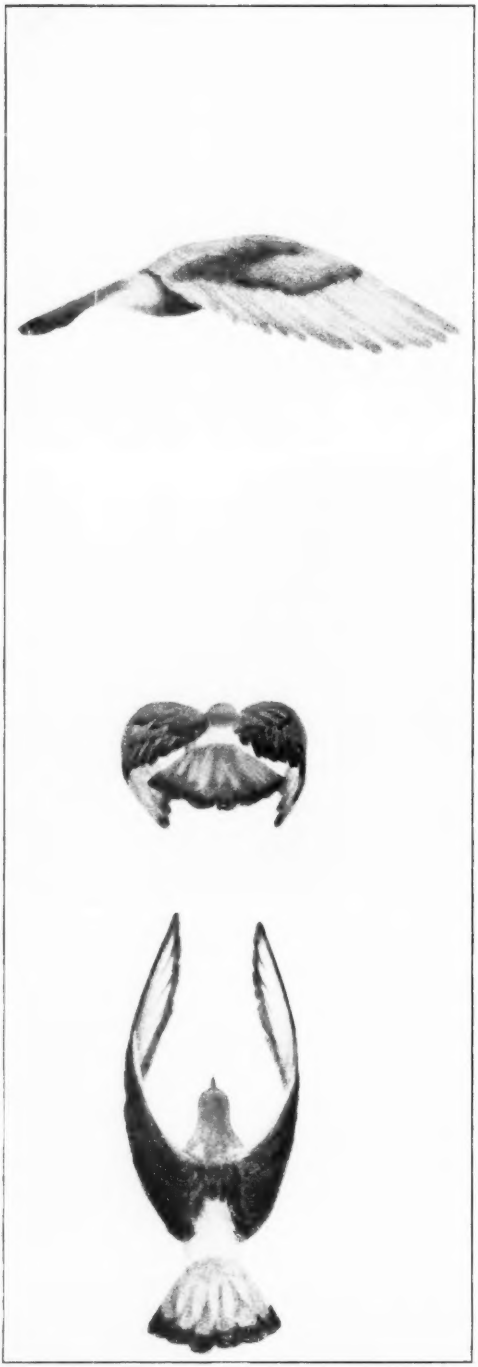
*Speed and acceleration components of the wing-tip.*

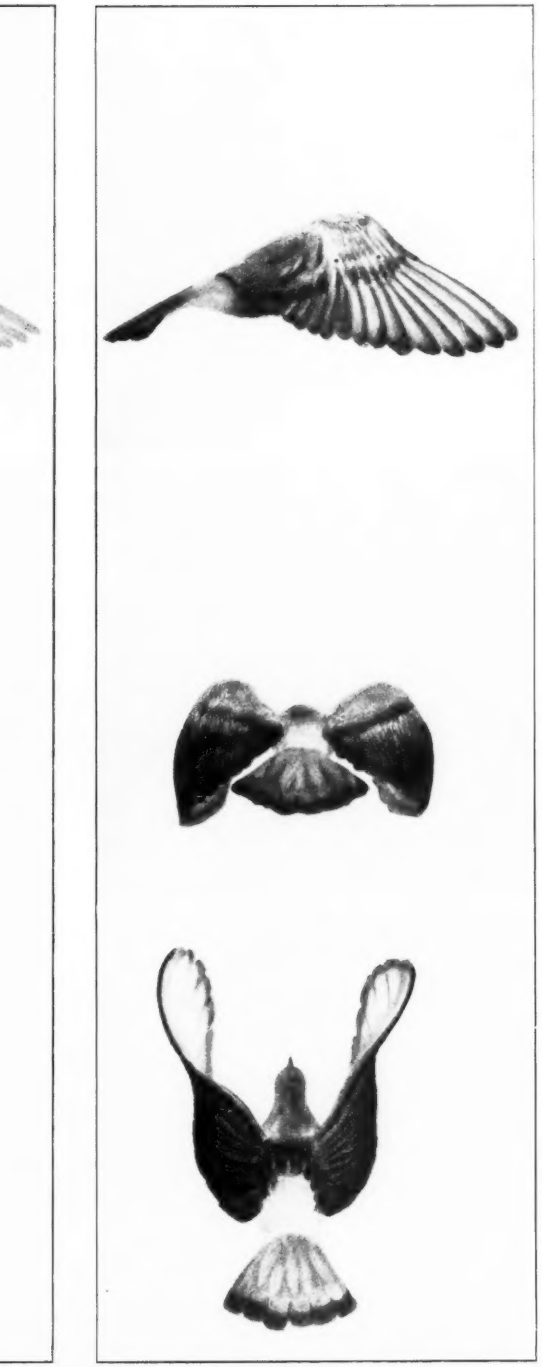
induce a mass reaction in the air, because the wing incidence is almost nil. This is essentially a movement of preparation for the ascending phase, in which the wing is contracted until its spread is only half that which corresponds to the downward phase; at the same time, as I said before, the feathers spread out and rotate elastically around the calamus, making a "Venetian blind" surface which offers minimum resistance to the upward motion.

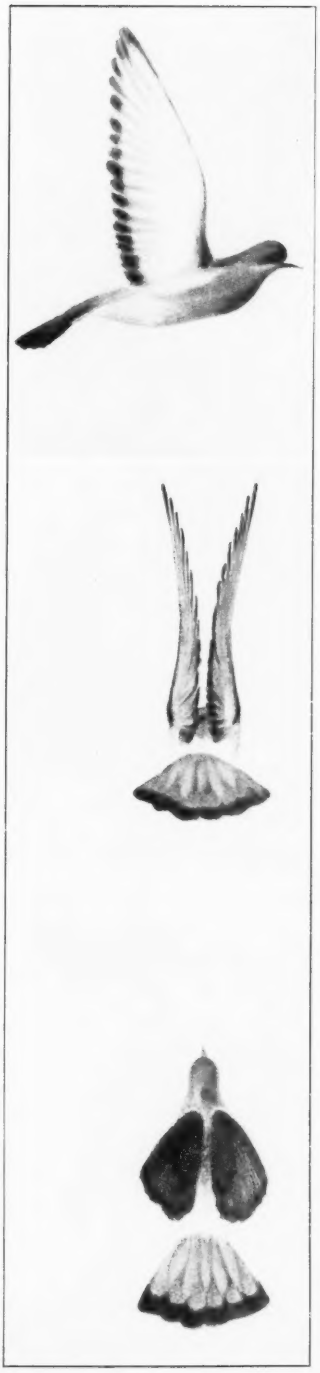
A study of the photograms, whilst it shows in the downward phase positions and attitudes which are natural and might be foreseen, reveals in the upward phase movements which are unexpectedly complex and attitudes which would be incredible were they not substantiated by the photographs. The complexity of these movements and the laws which govern them, of which it is now possible for the first time to make a close analysis—not to mention the high values of the accelerations—show that the theoretical study of beating-wing flight must take a new trend, because until now various elements of primary importance have been left out of count.

| Field | Section | Speeds. Horizontal Longitudinal | Horizontal Lateral | Vertical | Total | Accelerations. Horizontal Longitudinal | Horizontal Lateral | Vertical | Total |
|---|---|---|---|---|---|---|---|---|---|
| I | 1 | 8.7 | 12.5 | 7.1 | **16.8** | −333 | 564 | 795 | **1030** |
| | 2 | 6.8 | 12.3 | 11.1 | **17.9** | −487 | 51.2 | 1025 | **1136** |
| | 3 | 6.5 | 10.8 | 14.9 | **19.5** | −77 | −385 | 975 | **1051** |
| | 4 | 7.1 | 7.6 | 16.2 | **19.3** | 154 | −820 | 333 | **898** |
| II | 1 | 9.2 | 1.4 | 14.8 | **17.5** | 538 | −1590 | −359 | **1716** |
| | 2 | 12.7 | −5.9 | 12 | **18.4** | 898 | −1870 | −718 | **2195** |
| | 3 | 14.8 | −13 | 9.4 | **21.8** | 538 | −1820 | −666 | **2011** |
| | 4 | 15.2 | −15.8 | 6.9 | **23** | 102 | −718 | −641 | **968** |
| III | 1 | 13.7 | −13 | 4.6 | **19.4** | −385 | 718 | −589 | **1005** |
| | 2 | 10.3 | −5.5 | 3.8 | **12.3** | −873 | 1920 | −204 | **2119** |
| | 3 | 6.3 | 1 | 1.5 | **4.3** | −1025 | 1150 | −589 | **1649** |
| | 4 | 4.7 | 3.9 | −0.7 | **6.1** | −411 | 745 | −564 | **1021** |
| IV | 1 | 5.5 | 4.7 | −3.1 | **7.9** | 204 | 204 | −615 | **703** |
| | 2 | 6.9 | 4.4 | −5.7 | **10** | 359 | −77 | −666 | **761** |
| | 3 | 7.2 | 3.9 | −8.2 | **11.5** | 77 | −128 | −641 | **584** |
| | 4 | 6.8 | 3 | −10.5 | **12.9** | −102 | −231 | −589 | **689** |
| V | 1 | 5 | 2.5 | −11 | **12.3** | −462 | −128 | −128 | **496** |
| | 2 | 1 | 2 | −11 | **11.2** | −1025 | −128 | 0 | **1033** |
| | 3 | −4.2 | 1.8 | −10.5 | **11.5** | −1330 | −51.2 | 128 | **1337** |
| | 4 | −7.3 | 1 | −9 | **11.6** | −795 | −204 | 385 | **907** |
| VI | 1 | −6 | −0.7 | −7.8 | **9.9** | 333 | −436 | 308 | **629** |
| | 2 | −3.3 | −2.5 | −7 | **8.1** | 693 | −462 | 204 | **857** |
| | 3 | 0.5 | −3.7 | −6.5 | **7.5** | 975 | −308 | 128 | **1030** |
| | 4 | 4 | −4.2 | −5.6 | **8.1** | 898 | −128 | 231 | **936** |
| VII | 1 | 6.2 | −4.2 | −4.4 | **8.7** | 564 | 0 | 308 | **634** |
| | 2 | 7.8 | −4 | −2.9 | **9.2** | 411 | 51.2 | 385 | **565** |
| | 3 | 8.5 | −3.8 | −1.7 | **9.5** | 179 | 51.2 | 308 | **360** |
| | 4 | 9 | −3.5 | −0.9 | **9.7** | 128 | 77 | 204 | **253** |
| VIII | 1 | 9 | −3 | −0.7 | **9.5** | 0 | 128 | 51.2 | **138** |
| | 2 | 9 | −2.8 | −0.5 | **9.6** | 0 | 51.2 | 51.2 | **72** |
| | 3 | 9 | −2.6 | −0.3 | **9.4** | 0 | 51.2 | 51.2 | **72** |
| | 4 | 9 | −2 | 0.1 | **9.3** | 0 | 154 | 102.5 | **185** |
| IX | 1 | 9.4 | 2.5 | 1 | **9.8** | 102.5 | 1150 | 231 | **1177** |
| | 2 | 10 | 10.2 | 4 | **14.8** | 154 | 1970 | 768 | **2120** |









# NOTE ON LORD RAYLEIGH'S RECIPROCAL THEOREMS IN ELASTIC SYSTEMS.

By J. Morris, B.A.

Reciprocal theorems are valuable devices in the attack on strength, stiffness and vibration problems in structures, often leading to elegant and simple solutions. Reciprocity is a fairly common property in various coefficients which arise in mathematical physics, as for example coefficients of mutual potential, capacity, induction, and so on. It is inevitably encountered both in theory and practice in almost any branch of physical science. So far as the stiffness of structures is concerned it seems that while Hooke is the mainspring of the theory of elasticity Rayleigh is the regulator of reciprocal relations in elastic systems.

As Rayleigh's reciprocal theorems provide powerful means for the solution of problems of the statically indeterminate type, it may not be out of place to give a short historical résumé of the development of the main lines of attack on such problems. From Todhunter and Pearson's history of elasticity and strength of materials, it would appear that it was Francesco Bertelli who in 1843, in a paper read before the Bologna Academy, first called attention to the fact that the solution of a statically indeterminate problem could not be reached without the aid of the theory of elasticity. Lamé in a *Note sur la théorie de l'élasticité des corps solides* published in *Comptes Rendus* in 1852 alludes to a theorem by Clapeyron concerning which he says: "*M. Clapeyron a découvert un théorème général, qui mérite le nom de principe du travail des forces lastiques.*" In *Comptes Rendus* in 1858 there was published a résumé of a memoir by Clapeyron in which he considered how the work of an elastic body could be expressed. In the same volume and the same year there appeared Menabréa's "*nouveau principe sur la distribution des tensions dans les systèmes élastiques.*" In this memoir the principle of least internal work for a redundant pin-jointed frame appears to be given for the first time. Castigliano's proof of this principle as given in his treatise "*Théorie de l'équilibre des systèmes élastiques*" published in 1879 is an improvement on Menabréa's, but does not actually prove that the internal work is a minimum. He does, however, establish in a satisfactory manner that the work is stationary.

Maxwell in his paper "On the calculation of the equilibrium and stiffness of frames" which was published in the *Phil. Mag.* in 1864 (Vol. 27) and which deals with the redundant pin-jointed frame makes special reference to Clapeyron's theorem which was based on the principle of the equality between internal and external work. Maxwell noticed some particular cases of reciprocity the chief of which in reference to a frame seems to be that which he gives as follows:—"Theorem. The extension in $BC$ due to unity of tension along $DE$ is always equal to the extension in $DE$ due to unity of tension in $BC$." It appears that on the strength of this particular reciprocal theorem the general laws of reciprocal deflections in beams and the like are erroneously attributed to Maxwell by various authorities, particularly American.

In his paper "a statical theorem" published in the *Phil. Mag.* in 1874 (Vol. XLVIII, pp. 452-6) Rayleigh gave a number of reciprocal relations in elasticity some of which in particular cases must have been noticed before, as for instance, the theorem given by Maxwell; indeed Rayleigh in this classic paper says "the statical theorem to which the general principle reduces is so extremely simple that it can hardly be supposed to be altogether new, nevertheless it is not to be found in any of the works on mechanics to which I have access, and was not

known to the physicists to whom I have mentioned it." So impressed was Rayleigh by these reciprocal properties that he carried out experiments to verify them practically, and published the results in the *Phil. Mag.* in 1875 (Vol. XLIX, pp. 183-5).

Now Rayleigh's reciprocal theorem in statics was deduced by him from a more general dynamical reciprocal theorem which was published in 1873. Love, in his elasticity, in a footnote to paragraph 121, entitled " The reciprocal theorem," says " the theorem is due to E. Betti, *Il. nuovo cimento tt.* 7 and 8 (1872). It is a special case of a more general theorem given by Lord Rayleigh. *London Math. Soc. Proc.*, Vol. 4 (1873), or *Scientific Papers*, Vol. I, p. 179."

From Rayleigh's general theorem a variety of reciprocal properties pertaining to particular cases may be deduced. Three important ones included amongst those given by Rayleigh are :—

For a rod (not necessarily uniform in section) supported horizontally in any manner,

(i) If $P$ and $Q$ be any two points on it, any load attached to $P$ will produce the same linear deflection at $Q$ as is observed at $P$ when the same load is transferred to $Q$.

(ii) A given couple at $P$ will produce the same rotation at $Q$ as the same couple at $Q$ would produce at $P$.

(iii) A couple at $P$ would do as much work, in acting over the rotation at $P$ due to a simple force at $Q$ as the force at $Q$ would do in acting over the linear displacement at $Q$ due to the couple at $P$.

# ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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*(Prepared by R.T.P.)*

No. 67. MAY, 1939.

*The Air Power of Germany.* (M. Muratori, Inter. Avia., No. 633-4, 12/4/39, pp. 1-3.) (67/1 Italy.)

According to Italian sources, the first line strength of the German Air Force amounted to 3,000 machines in June, 1938.

The principal types then in use are given in the following table:—

| Mission. | Type. | Top speed m.p.h. | Range (m.). | Bomb load lb. | Armament |
|---|---|---|---|---|---|
| Bombers ... | He 111 | 310 | 930 | 4,400 | 3 M.G. |
| | Ju 86 | 230 | 670 | 2,200 | 3 M.G. |
| Dive Bombers | Hs 123 | 250 | 370 | 660 | 2 M.G. |
| | He 108 | 250 | 870 | 1,100 | 1 M.G. 1 S.G. |
| Fighters ... | Bf 109 | 310 | 370 | — | 3-4 M.G. |
| | He 112 | 300 | 685 | 130 | 4 M.G. |
| Reconnaissance | Do 17 | 300 | 930 | 1,100 | 3 M.G. |
| | He 70 | 225 | 1,300 | 660 | 2 M.G. |
| | Hs 112 | 175 | 600 | — | 2 M.G. |

In April, 1939, the first line strength had been doubled (6,000 machines), new types replacing at the same time some obsolescent machines.

| Mission. | Type. | Top speed 13,000 ft. m.p.h. | Range. | ARMAMENT. M.G. or S.G. | Bomb Load lb. | Power plant. |
|---|---|---|---|---|---|---|
| Bomber ... | Ju 88 | 280 | — | 3 M.G. | 3,100 | 2 D.B. 601 = 2,400 |
| | He 111 | 280 | 930 | 3 M.G. | 4,400 | 2 D.B. 601 = 2,400 |
| | Do 172 | 280 | 500 | 3 M.G. | 2,200 | 2 Jumo 211 = 2,200 |
| Dive Bomber ... | Ju 87 | 240 | 500 | 3 M.G. 1 S.G. | 1,100 | 1 Jumo 211 = 1,100 |
| Fighter ... | He 112 | 290 | 680 | 2 M.G. 2 S.G. | 130 | 1 Jumo 210 = 685 |
| | Bf 109 | 320 | 370 | 3-4 M.G. | — | 1 D.B. 601 = 1,200 |
| | Bf 110 | 350 | — | 4 M.G. 2 S.G. | — | 2 D.B. 601 = 2,400 |
| Reconnaissance (long range) | Do-17F | 230 | 1,250 | 2 M.G. | 880 | 2 D.B. 600 = 1,820 |
| Do. (short range) | Hs 126 | 220 | 590 | 2 M.G. | 220 | 1 BMW 132 = 870 |

Outstanding types in the above table are the Ju 88, credited with a considerably higher speed than 280 m.p.h. and the twin-engined fighter Bf 110.

The almost exclusive employment of D.B. and Jumo engines should be noted.

Of the total first line strength, 3,000 machines are bombers, 2,000 fighters and 1,000 reconnaissance aircraft.

*Emergency Repairs of Fractured Gas and Water Mains (A.R.P.).* (Engineering, Vol. 147, No. 3821, 7/4/39, p. 410.) (67/2 Great Britain.)

The connection to the broken main is made by a sleeve. This is slipped over the fractured end which may, if necessary, be roughly squared with a hammer, and is held firmly in place by set-screws disposed radially. The seal is made by a heavy rubber ring, held in place by a ring not unlike an inverted gland, and tightened up by bolts. Attached to the sleeve by a Victualic joint is a reducing piece to which bends and pipes are coupled. It will be clear that the sleeve must conform to the external diameter of the main concerned which means that the undertaking would have to stock it, complete with reducers, in sizes determined by its mains. The bridging pipes and bends, being of standard sizes, may be stocked as may be considered necessary; it is possible, for instance, that only one bore of pipes and bends would be needed.

*Method of Observation for Artillery.* (Rev. de l'Arm. de l'Air, No. 114, Jan.-Feb., 1939, pp. 83-85.) (67/3 Germany.)

There are two main types of artillery targets:—

(1) Enemy batteries.

(2) Troops.

In either case observation by aircraft has been of the greatest use in the past. Modern A.A. artillery may however force the observation plane to remain well behind the first line (4 km.). This requires special low speed aircraft to enable the observer to use binoculars of high magnification, whilst flying in a circle. Even then the oblique view is unsatisfactory and the author gives a list of alternative methods of observation in order of distance of observer from the front line:—

(1) 20 m. ladder.
(2) Trench mortar projecting camera attached to parachute (altitude several hundred meters).
(3) Small balloon or captive helicopter carrying camera (1,000 m.).
(4) Free flying helicopter with observer (2,000 m.).
(5) Normal observation aircraft (up to 5,000 m.).
(6) Motorised observation balloon, filled with helium (1,500 m.).
(7) Normal observation balloon, filled with hydrogen (2,000 m.).

(1), (2) and (3) would operate within 1 km. of the front line, (4) at 3 km., whilst (6) and (7) are generally placed well to the rear (5.5 and 7.5 km. respectively).

In addition the author refers to the possibility of small wireless controlled aircraft for taking photographs from an altitude of about 1,500 m. at an average distance of 2 km. from the front line.

*Fire at Manœuvring Aircraft.* (G. A. Chester, Coast Artillery Journal, Vol. 82, No. 2, March-April, 1939, pp. 114-125.) (67/4 U.S.A.)

1. There are certain definite limits of manœuvre, set by the aerodynamic and structural design of the aeroplane, and wholly independent of the desire or skill of the pilot. The existence of these limits simplifies the problem of firing against manœuvring aircraft and knowledge of these limits is of great value to a manœuvring adjusting officer attempting to fire effectively on a manœuvring target.

2. Bombsights are likely to appear in the near future that will make it practical to bomb from a steady glide. Present directors are not designed to fire automatically on gliding targets; and firing effectively with present directors requires a specialised technique and organisation.

3. Under zigzag, repetitive manœuvres (of which the *S* curve is an example) it may be desirable to have the trackers average the course by eye and fire down its centre.

4. Artificial dispersion is desirable when firing on certain types of manœuvres. Most manœuvres can be countered by one of four burst patterns, and some means of producing these burst patterns is desirable.

*The Technique of Building Demolition.* (G. Loesch, Z.V.D.I., Vol. 83, No. 18, 22nd April, 1939, pp. 457-762.) (67/5 Germany.)

After considering the more usual methods of demolition (pick-axe and pneumatic drill) the author deals with the utilisation of explosives. This new method has been used extensively in recent reconstruction work in Berlin. In the case of ferro-concrete building, high explosives cause the concrete to part from the steel frame and the building can be caused to collapse in stages without danger to the neighbourhood. Foundations are best destroyed by using liquid oxygen as an explosive. This method has been developed by Wiethuchter and consists of a combination of carbon and liquid oxygen, the mixture being fired by means of a thermite primer. The explosion is local and there is very little splinter action.

*Constructional Work on Air Raid Shelters and Other Protective Work.* (R. W. G. Clarke, J. Inst. Civ. Eng., Vol. 11, No. 6, April, 1939, pp. 573-84.) (67/6 Great Britain.)

The works described have either been constructed or are under construction and are applicable to a wide variety of site and other conditions. Whilst not exhaustive, they represent the application of Home Office and other A.R.P. recommendations.

Protection from direct hits from high explosive bombs do not come under consideration.

The works cover:—

1. Protection of personnel from:—
   - (*a*) Gas and incendiary bombs.
   - (*b*) Light explosive bombs.
   - (*c*) Impact and penetration from (*a*) and (*b*).
   - (*d*) Blast and fragmentation.
   - (*e*) Demolition.
   - (*f*) Concussion.
2. Protection of power plant from:—
   - (*a*) Incendiary bombs.
   - (*b*) Light explosive bombs.
   - (*c*) Impact and penetration from (*a*).
   - (*d*) Blast and fragmentation.

On a capacity basis the shelters cost from £8 to £10 per head. This figure compares very favourably with trench-type shelters, the costs of which run as follows:—

| | | |
|---|---|---|
| Open trenches ... ... ... ... | £2 0 0 | per head. |
| Riveted timber sides ... ... ... | £3 17 0 | ,, |
| With roof of corrugated iron, etc. ... | £9 0 0 | ,, |

*Development Trends in the Design of Fighter Aircraft.* (Inter. Avia., No. 642, 9th May, 1939, pp. 1-4.) (67/7 Switzerland.)

The present day standard type single-seat fighter will maintain itself in the immediate future with increased engine power and speed improvements of up to

at least 435 m.p.h. Its development, however, may be assumed to result in the transfer of the engine to the centre of gravity, eventually with the use of counter-revolving airscrews (once the problem of controllability has been solved). Furthermore, an improvement in the landing gear may be anticipated, probably by the changeover to the nose-wheel design. Concurrently, the development of the twin-engined single-seat fighter and multi-seat fighter will doubtlessly make further progress and speeds equalling those of the single-engined single-seat fighter may be expected.

*Turbulence and Diffusion.* (H. L. Dryden, Ind. and Eng. Chem. (Industrial Edition), Vol. 31, No. 4, April, 1939, pp. 416-425.) (67/8 U.S.A.)

Modern developments in the experimental and theoretical aspects of turbulence in relation to the process of diffusion are reviewed. The concept of isotropic turbulence, its description in terms of the statistical properties designated " intensity and scale," and its experimental realisation are discussed at some length. Taylor's theory of diffusion by continuous movements is described and illustrated by his application of the theory to the diffusion of heat from a line source in an air stream with isotropic turbulence. At distances downstream which are small in comparison with the scale of turbulence, the diffusion depends only on the intensity of the turbulence; at large distances, the scale of the turbulence is also an important factor.

Reynolds' description of non-isotropic turbulence is given in terms of mean values of products of fluctuations of the velocity components and of the methods now available for measuring these mean values in two-dimensional flow. Von Kármán's description of the scale characteristics of non-isotropic turbulence in terms of correlation tensors is briefly stated.

Recent results on the mixing of jets with the surrounding air are briefly reviewed, and the essential difference between diffusion of momentum and diffusion of heat or matter (smoke, dye) is pointed out, namely, that the diffusion of momentum is affected by pressure gradients whereas no corresponding factor occurs in the diffusion of heat or matter. Hence the parallel between skin friction and heat transfer is invalid except in special cases.

The practical means of securing large turbulence to promote rapid mixing is discussed as applied to continuous processing, namely, by turbulent flow in a pipe, by jets emerging in quiescent air or in a counter current, and by turbulence in the wake of obstacles.

*Fluid Resistance in Pipes.* (M. P. O'Brien, R. G. Folson and F. Jonassen, Ind. and Eng. Chem. (Industrial Edition), Vol. 31, No. 4, April, 1939, pp. 477-81.) (67/9 U.S.A.)

Formulæ based on the theory of fully developed turbulent flow and on experiments using artificially roughened pipes are applied to extrapolated data for commercial pipes in order to obtain the equivalent roughness. Using this roughness, it is found that clean pipes do not follow a curve similar to that of Nikuradse in the transition zone between rough and smooth flow conditions. The conclusion is drawn that the turbulence theory has not yet provided a reliable generalised treatment of pipe resistance in the region important in engineering problems.

*Eddy Diffusion.* (W. L. Towle and T. K. Sherwood, Ind. and Eng. Chem. (Industrial Edition), Vol. 31, No. 4, April, 1939, pp. 457-62.) (67/10 U.S.A.)

Diffusion experiments were carried out at points 60 to 70 diameters downstream from the inlet ends of two ducts, 30.5 and 15.24 cm. in diameter, with air in turbulent flow at Reynolds numbers from 12,000 to 180,000. Carbon dioxide and hydrogen were introduced at the axis of the duct, and concentration

traverses over the central third of the duct diameter were obtained at points up to 4 metres downstream. The results were interpreted in terms of the calculated values of the eddy conductivity, $E$, obtained by comparing the data with an adaptation of the Wilson equation for heat dissipation from a continuous point heat source in a moving stream. The values of $E$ obtained were of the order of 100 times the molecular diffusivity, and were the same for hydrogen as for carbon dioxide. $E$ was found to approach an asymptote with increase in distance between injector tube and sampling traverse. The asymptotic values of $E$ increased approximately proportionally to increase in Reynolds number.

*Effect of a Screen Grid on the Turbulence of an Air Stream.* (W. L. Towle, T. K. Sherwood and L. A. Seder, Ind. and Eng. Chem. (Industrial Edition), Vol. 31, No. 4, April, 1939, pp. 462-3.) (67/11 U.S.A.)

The technique previously developed for measuring diffusion in a turbulent gas stream was employed to study the turbulence conditions downstream from a wire screen grid in a 30.5 cm. duct. The eddy diffusivity, $E$, was obtained in the region from 0.5 to 62.5 duct diameters downstream from the grid. In the first 15 diameters downstream, $E$ was less than half the value obtained with no grid present, but increased to approach an asymptote at about 45 diameters downstream. The asymptotic value was approximately equal to that obtained at the same Reynolds number with no grid.

*Summary of N.A.C.A. Investigations of High Lift Devices.* (C. J. Wezinger, J.S.A.E., Vol. 44, No. 4, April, 1939, Transactions, pp. 161-72.) (67/12 U.S.A.)

Various basic arrangements of high-lift flaps investigated by the N.A.C.A. are grouped for comparison. The comparisons made in this figure are of the wing section, or infinite aspect ratio characteristics, corresponding to an effective Reynolds number of 3,500,000. The characteristics considered are the maximum lift coefficient, the increment of maximum lift coefficient due to the lift-increasing device and the ratio of maximum lift to minimum drag which is an indication of the speed range obtainable with a given combination.

The slotted types of flap appear to be the most promising on the basis of the aerodynamic characteristics listed; the N.A.C.A. arrangement of the double-slotted flap (unpublished) shows up the most favourable of the entire group.

With supplementary equipment, several investigations have been made in the wind tunnel of model wings on which the boundary layer has been controlled by an external blower connected to the wing. These test results and other results from unpublished data indicate that, in general, lift coefficients of over 3.0 at large angles of attack could be obtained experimentally with relative small power required for the blower. Data available at the present time are believed to be insufficient for application to designs incorporating the foregoing types of boundary layer control methods. (52 references.)

*Some Phases of Wind Tunnel Work.* (H. L. Dryden, J.S.A.E., Vol. 44, No. 4, April, 1939, p. 22.) (67/13 U.S.A.)

Starting with a brief description of early wind tunnels, the author mentions discrepancies observed in measured drag coefficients of sphere, and describes briefly Prandtl's classical explanation of the phenomenon. Modern methods of measuring the intensity and scale of wind tunnel turbulence, and the correlation of these two into a single turbulence parameter as suggested by G. I. Taylor are next discussed. The relation of critical Reynolds number of spheres to this parameter as determined in a number of wind tunnels is shown, and the significance of these results in indicating the very low turbulence existing in free air is pointed out. The general trend of wind tunnels is towards lower turbulence

and the significance of this trend in leading to improved understanding and prediction of aerodynamic characteristics in flight is discussed.

In conclusion, the author exhibits the classical laminar and turbulence skin friction curves, and points out the significance of the transition point in practical aerodynamic problems.

*Determination of Boundary Layer Transition on Three Symmetrical Aerofoils in the N.A.C.A. Full-Scale Wind Tunnel.* (A. Silverstein and J. V. Becker, N.A.C.A. Report No. 637, 1939.) (67/14 U.S.A.)

For the purpose of studying the transition from laminar to turbulent flow, boundary layer measurements were made in the N.A.C.A. full-scale wind tunnel on three symmetrical aerofoils of N.A.C.A. 0009, 0012 and 0018 sections.

The results indicate no unique value of Reynolds number for the transition, whether the Reynolds number is based upon the distance along the chord or upon the thickness of the boundary layer at the transition point. In general, the transition is not abrupt and occurs in a region that varies in length as a function of the test conditions. With increasing lift, the transition on the upper surface moves toward the forward stagnation point; whereas, on the lower surface, the transition progresses in the opposite direction. This effect is most marked for the thin aerofoils. The total head tubes and hot wires indicate essentially the same point of transition. Profile drag results are given and a correlation of the drag and the transition measurements is attempted.

*The Compressibility Burble and the Effect of Compressibility on Pressures and Forces Acting on an Aerofoil.* (J. Stack, W. F. Lindsey and R. E. Littell, N.A.C.A. Report No. 646, 1939.) (67/15 U.S.A.)

Simultaneous airflow photographs and pressure distribution measurements were made of the N.A.C.A. 4412 aerofoil at high speeds to determine the physical nature of the compressibility burble. The tests were conducted in the N.A.C.A. 24-inch high speed wind tunnel.

The data presented include the results of pressure distribution measurements and force tests for three low angles of attack for a speed range extending from one-tenth the speed of sound to speeds in excess of the critical values at which a breakdown of the flow, or compressibility burble, occurs.

The results show the general nature of the phenomenon known as the compressibility burble. The source of the increased drag is shown to be a compression shock that occurs on the aerofoil as its speed approaches the speed of sound. Finally, it is indicated that considerable experimentation is needed in order to understand the phenomenon completely.

*Downwash and Wake Behind Plain and Flapped Aerofoils.* (A. Silverstein, S. Katzoff and W. K. Bullivant, N.A.C.A. Report No. 651, 1939.) (67/16 U.S.A.)

Extensive experimental measurements have been made of the downwash angles and the wake characteristics behind aerofoils with and without flaps and the data have been analysed and correlated with the theory. A detailed study was made of the errors involved in applying lifting-line theory, such as the effects of a finite wing chord, the rolling-up of the trailing vortex sheet, and the wake.

The downwash angles, as computed from the theoretical span load distribution by means of the Biot-Savart equation, were found to be in satisfactory agreement with the experimental results. The rolling-up of the trailing vortex sheet may be neglected, but the vertical displacement of the vortex sheet requires consideration.

By the use of a theoretical treatment indicated by Prandtl, it has been possible to generalise the available experimental results so that predictions can be made

of the important wake parameters in terms of the distance behind the aerofoil trailing edge and the profile drag coefficient.

The method of application of the theory to design and the satisfactory agreement between predicted and experimental results when applied to an aeroplane are demonstrated.

*Comparison of Profile Drag and Boundary Layer Measurements Obtained in Flight and in the Full-Scale Wind Tunnel.* (H. J. Goett and J. Bicknell, N.A.C.A. Tech. Note No. 693, March, 1939.) (67/17 U.S.A.)

The effect of the existing turbulence in the full-scale tunnel was determined from measurements of the profile drag of an N-22 section by the momentum method under corresponding conditions in flight and in the tunnel. The transition point location on the upper surface of the aerofoil was also determined from velocity surveys in the boundary layer. The measurements were made at section lift coefficients from 0.480 to 0.635 with a range of Reynolds numbers from 3,900,000 to 4,600,000.

The results show that the end of transition occurs at approximately the same point on the aerofoil in flight and in the tunnel. The transition region was somewhat broader in the tunnel and started farther forward than in flight. The laminar profiles in the tunnel had some characteristics of transition profiles and had a much steeper slope, $\partial u/\partial y$, near the surface than did the laminar profiles obtained in flight. These differences, however, caused an increase of only 0.0001 in the profile drag coefficients, as determined by the momentum method.

*The Effect of Some Common Surface Irregularities on Wing Drag.* (M. J. Hood, N.A.C.A. Tech. Note No. 695, March, 1939.) (67/18 U.S.A.)

The N.A.C.A. has conducted tests to provide more complete data than were previously available for estimating the effects of common surface irregularities on wing drag. The irregularities investigated included: Brazier head and countersunk rivets, spot welds, several types of sheet metal joints, and surface roughness. Tests were also conducted to determine the over-all effect of manufacturing irregularities incidental to riveted aluminium alloy and to spot-welded stainless steel construction. The tests were made in the 8-foot high speed wind tunnel at Reynolds numbers up to 18,000,000.

CONCLUSIONS.

1. Rivets at $\frac{3}{4}$ inch pitch in 13 spanwise rows on each surface of an aerofoil at 5-foot chord increased the drag from 6 per cent. for countersunk rivets to 27 per cent. for $\frac{3}{32}$ inch brazier head rivets. About 70 per cent. of these drag increments were due to the rivets on the forward 30 per cent. of the aerofoil.

2. Lapped joints, arranged six on each surface, increased the drag of the aerofoil from 4 per cent. for joggled laps to 9 per cent. for conventional laps.

3. Surface roughness may cause serious increases in drag; for example, the roughness due to spray painting increased the drag 14 per cent. and roughness of 0.0013 inch grain size increased the drag 42 per cent.

4. Manufacturing irregularities increased the drag of a typical wing 8 per cent. of the smooth wing drag over and above the increments due to the rivets and lapped joints.

*Investigation of the Lift Distribution Over the Separate Wings of a Biplane.* (D. Kuchemann, L.F.F., Vol. 15, No. 10-11, 10th October, 1938, pp. 543-5. Available as Translation T.M. 889.) (67/19 U.S.A.)

An investigation is made of the mutual interference of the wings of a biplane under the general assumption that each wing may be replaced by a vortex system of the type given by the Prandtl wing theory. The additional velocities induced at each wing by the presence of the other are determined by the Bivot-Savart law

and converted into an equivalent change in angle of attack, the effect being that of an additional twist given to the wings in changing their lift distributions. The lift distributions computed in this manner for several aeroplane types are compared with the results of measurement.

*Propulsion and Resistance.* (W. Schmeidler, Z.A.M.M., Vol. 19, No. 2, April, 1939, pp. 65-86.) (67/20 Germany.)

The author considers the flow phenomena accompanying the periodic motion of a wing in an airstream, paying particular attention to the calculation of propulsion and resistance. The investigation differs from previous work on this subject in that general expressions are obtained depending essentially on the periodical variation of the distribution of circulation about the wing.

Taking first the two-dimensional case, it is shown that a periodic variation in the distribution of the circulation produces in all cases a positive mean resistance, but that the ratio of propulsion to resistance (for horizontal flight at a given velocity and frequency) can be made as large as required by having a sufficiently flexible wing.

In the three-dimensional case, both the transverse and longitudinal vortices shed by the wing are considered. The distribution of circulation round the wing is assumed to be that of a series of bound vortex filaments in the direction of the span, the circulation vanishing at the end of the filament. The general equations are simplified by assuming that $\gamma b/\mu$ is small, $\gamma$ = frequency, $b$ = span, $\mu$ = incident air speed. For a given span distribution of the circulation the chord distribution giving maximum net propulsion is calculated.

*Variation in Velocity Profile with Change in Surface Roughness of Boundary.* (W. Jacobs, Z.A.M.M., Vol. 19, No. 2, April, 1939, pp. 87-100.) (67/21 Germany.)

The phenomena accompanying fully established turbulent flow along a boundary of known roughness may be considered as being now understood. Expressions have been obtained for smooth and rough tubes and channels for the velocity distribution, resistance, exchange in impulse and the mixing path. If the surface roughness undergoes a change a new velocity profile has to be formed and this transition region has so far been investigated only theoretically, making certain simplifying assumptions. The author has carried out experiments over this region and utilised the results to establish a new method for calculating the velocity distribution over the transition section of a channel when changing from smooth to rough and vice-versa, provided the shear stress at the wall under conditions of fully established flow is known. The predictions have been confirmed by further experiments.

*Flow Phenomena at Nozzles and Orifices.* (P. Jordan, Forschung, Vol. 10, No. 2, March-April, 1939, pp. 88-92.) (67/22 Germany.)

The experiments were carried out in a rectangular water channel of special design, the flow being rendered visible by the introduction of a special dye. This colouring matter was either introduced into the stream or emitted from a series of holes on the surface of the nozzle or orifice plate (two-dimensional models only).

The Reynolds numbers ranged from $10^4$ to $10^5$ and photographs are given showing typical boundary layer phenomena. It is hoped by further studies of this kind to clear up certain anomalies noted in the calibration of nozzles and orifices and thus increase the accuracy of flow measurements.

*The Design of Jet Pumps (Injectors and Ejectors).* (G. Flugel, Forschungsheft, No. 395, March-April, 1939, pp. 1-21.) (67/23 Germany.)

The theory of jet pumps is still rather incomplete and relatively little has been published so far. Successful designs have been developed by trial and error and

information obtained in this way is naturally guarded by the various firms concerned.

The author shows that by applying both the energy and impulse theorems, the optimum dimension of the collector throat and best shape of intake can be determined approximately in a relatively simple manner.

The necessary length of the collector follows from Prandtl's turbulent mixing theory.

The calculations are carried out for the mixing of similar and dissimilar fluids.

*The Application of Electrical Equipment to Aircraft.* (O. F. Olsen, J.S.A.E., Vol. 44, No. 4, April, 1939, p. 12.) (67/24 U.S.A.)

The author surveys the fundamental considerations involved in the application of electrical equipment to aircraft. Factors are reviewed that establish the rating of electrical equipment. Important limitations due to materials used in the construction of apparatus are noted, and how they may be influenced by some of the new developments. The adaptability of standard industrial equipment to aircraft requirements is evaluated, with the modifications desired. The range of electrical characteristics is reviewed, with the underlying characteristics that influence their selection. The more important equipment and some of the relatively new devices are explained and their application characteristics noted. The requirements for the co-ordination of equipment into a complete, reliable, flexible, and adequate system are set forth.

*Feathering Propellers in Air Line Operation.* (M. G. Beard and E. W. Fuller, J.S.A.E., Vol. 44, No. 4, April, 1939, pp. 20-1.) (67/25 U.S.A.)

In this paper the full feathering principle is explained in two distinct propeller designs.

Performance figures are given for twin-engined air transport planes with and without feathering propellers, and the importance of the feathering propeller in the operation of four-engined aeroplanes and its beneficial effect upon twin and triple engine performance is pointed out. Propeller icing, pertinent flight test data, the value of the feathering propeller in studying propeller ice in flight, and future propeller design trends, also are discussed by the authors.

*A Report of Studies and Tests to Decrease Aircraft Fire Hazard.* (A. W. Dallas, J.S.A.E., Vol. 44, No. 4, April, 1939, p. 21.) (67/26 U.S.A.)

From the results of tests on the ignition of petrol and fuel oils in an airstream, the author concludes that fuel may be dumped safely from an aeroplane in flight, provided that it is discharged clear of the aeroplane structure. In his paper he reports the activities of the Technical Development Division of the Civil Aeronautics Authority in connection with aircraft fire hazards.

A comprehensive test programme is now being formulated by the Civil Aeronautic Authority, U.S.A., for the purpose of determining means of safeguarding aircraft from the dangers associated with power plant fires. These tests will be conducted on a full-scale nacelle and stub wing, complete with engine, propeller, and accessories. The engine will be operated, and the whole set-up placed in an air stream during the tests to simulate actual flight conditions. Tests will be made on fire detectors and fire extinguishers, and also on various materials and accessories, to determine suitable designs which will present the highest degree of safety from power plant fires.

*Résumé of Air Load Data on Slats and Flaps.* (C. J. Wenzinger and F. M. Rogallo, N.A.C.A. Tech. Note No. 690, March, 1939.) (67/27 U.S.A.)

A résumé of the generally available test data regarding air loads on slats and flaps is presented and data obtained up to the end of 1938 are included. The data are given in the form of N.A.C.A. standard coefficients of air forces and moments

on the lift increasing device and, when available, the aerodynamic characteristics of the combined wing and high lift device are included. Slats of the Handley Page type, fixed auxiliary aerofoils, and flaps of several different types are covered.

*Some Fundamental Considerations in Regard to the Use of Power in Landing an Aeroplane.* (W. S. Diehl, N.A.C.A. Tech. Note No. 692, March, 1939.) (67/28 U.S.A.)

This note is concerned with the effect of power on landing speed and apparent maximum lift coefficient. It is shown that when secondary effects are neglected, the maximum available increase in lift due to power is equal to the thrust being developed. If the increase in lift due to power is expressed in coefficient form, very high values may be shown under conditions which, on analysis, are found to be wholly impracticable in flight.

*Propeller Tests to Determine the Effect of Number of Blades at Two Typical Solidities.* (E. P. Lesley, N.A.C.A. Tech. Note No. 698, April, 1939.) (67/29 U.S.A.)

Propellers with equal total blade area, but with different numbers of blades, were tested.

The tests show generally that, for equal total blade area, propellers with the larger number of blades absorb the greater power and, provided hubs have equal drag, develop the higher efficiency.

It is shown that the differences found are in agreement, qualitatively, with what might be predicted from simple blade element theory.

*Piaggio P* 1001 *Controllable Pitch Airscrew.* (Inter. Avia., No. 638, 25th April, 1939, p. 7.) (67/30 Italy.)

Piaggio have produced a new controllable pitch airscrew, type P 1001, which differs from earlier Piaggio airscrews (Inter. Avia., No. 480) by a number of major improvements. The P 1001 airscrew permits the control of the blade pitch within any range up to the feathering position and is provided, furthermore, with an automatic constant speed control allowing any desired speed to be selected. The pitch changing energy is supplied by the engine torque, the control instrument operates electrically (current consumption 10 watts). The change to feathering position may be effected either mechanically, hydraulically or pneumatically. The new Piaggio airscrew may be fitted to any engine without necessitating any modifications to the latter. The operation of the pitch control installation by the pilot is very simple; it is sufficient to move a small lever on the control instrument to the desired blade pitch or to switch on the speed control.

*Messerschmitt Controllable Pitch Airscrew V.P.* 7. (Inter. Avia., No. 639, 28/4/39, pp. 7-8.) (67/31 Germany.)

The Messerschmitt A.G. of Augsburg has developed a controllable pitch airscrew, type V.P. 7, for special use on the Me. 108 " Taifun " high speed touring aeroplane. (Argus As 10 engine of 200-240 h.p.) This airscrew is of extremely low weight and of very simple design; changes in the blade pitch are effected manually by mechanical means.

CONSTRUCTION DETAILS.

The Messerschmitt V.P. 7 controllable pitch airscrew consists of two-coated light wood blades, patent Schwarz, with standardised Schwarz blade mounting. The steel hub is undivided and connected to the shaft by Hirth teething and a differential screw. Located on the hub shaft is a control ring, displaceable longitudinally and connected to the blade roots by short levers, thus making pitch changes possible. The displacement of the control ring is effected by a control traverse with internal Radiax ball bearings, mounted on gimballs on the engine

casing and operating in the manner of a lever. This control traverse is operated manually by the pilot (crank) via a rod system with Werner joints and a control spindle on the hub; the spindle is self-locking. Connected to the hand crank, which is arranged on the instrument board, is an indicating device on which the position for " take-off " and " cruising " are specially marked. All parts of the airscrew are exchangeable. The hub assembly includes a quickly dismantling spinner. Airscrew diameter 92½in. (2.55 m.), pitch change 10 deg., plus 2 deg. reserve, weight 82.5lb. (37.5 kg.), which is only about 20 kg. (44lb.) more than the weight of a fixed airscrew.

*A Discussion of Propeller Efficiency.* (H. M. McCoy, J. Aeron. Sci., Vol. 6, No. 6, April, 1939, pp. 227-234.) (67/32 U.S.A.)

A certain amount of confusion arises, due to the fact that propeller efficiency is defined in various ways.

(1) The " isolated " efficiency $= TV/(2\pi nQ)$ and refers to the propeller alone working in free air.

(2) The " apparent " efficiency refers to the same ratio, the propeller working close to a body. No evaluation is made of the effect of the slipstream on the body drag.

(3) The " net " efficiency is defined as $V(T-R)/(2\pi nQ)$. $T$ and $R$ represent the propeller thrust and body drag respectively, each being measured in the presence of the other. The combination of propeller and body is regarded as a propulsive unit.

(4) The " propulsive " efficiency $= V[T-(R-R_0)]/(2\pi nQ)$ where
$R_0$ = drag of body without propeller.
$(R-R_0)$ = increase in body drag due to slipstream.
$T$ = propeller thrust measured in presence of body.

$(R-R_0)$ is usually negative for cowled radial engines, *i.e.*, the slipstream decreases body drag.

The author presents a method of utilising " net " efficiencies to check level flight performance.

Attention is called to the great improvement in performance that can be expected by enclosing the engines within the aeroplane or wing structure and driving the propellers by extension shafts.

*Experiments with " Contact Lights " to Assist Fog Landings.* (Inter. Avia., No. 640, 2/5/39, p. 8.) (67/33 Great Britain.)

The lights are disposed in two parallel lines 65 yards apart along the line of approach indicated by the wireless beacon.

Outside the aerodrome boundary are placed six approach lights, 40 yards apart (sodium lights on the right and mercury lights on the left). Inside the aerodrome boundary are two strips of green lights (270 yards) followed by white (450 yards) and red (360 yards). These lights are set flush with the ground, the approach light being, however, tilted at an angle of 20° towards the incoming aircraft.

The flush lights are covered with glass lenses, capable of withstanding loads of the order of 10 tons per square foot.

*The Manufacture of Airscrews.* (Machinery, 27/4/39, pp. 93-103, p. 1. Metropolitan Vickers Technical News Bulletin, No. 659, 5/5/39, p. 1.) (67/34 Great Britain.)

This article describes the design and machining operations entailed in the manufacture of the Rotol constant speed hydraulically operated airscrew. The airscrew, which is of the three-bladed type, is controlled by a constant speed governor, so that the angular setting of the blades is fixed automatically during

flight by the position of the speed control lever; this acts direct on the governor mechanism and not on the engine throttle. A detailed explanation of the operating and reversing mechanism is given, and the production methods applied to the main components are outlined.

Illustrated with four diagrams, 20 photographs and one table.

*The Unit Power Plant (Rapidly Interchangeable Power Plant for Aircraft).* (W. Jellinghaus, Luftwissen, Vol. 6, No. 1, January, 1939, pp. 27-29. Available as Air Ministry Translation.) (67/35 Germany.)

The author describes the power installation developed by the Junkers works for the BMW. 132 H (radial) and Jumo 211 A (in-line V) engines.

In the former case the oil radiator and oil tank are placed inside the unit.

For the V engine, circular nose radiators, both for water and oil, are fitted. The power plant is attached by means of four lock nuts to the fireproof bulkhead. Provision is made for 22 pipes, six control rods and cables, and four electrical multiplied connections in the bulkhead.

The pipe connections are of the self-sealing type and special bayonet joints are provided for the control rods and cables. A special connector (not described) is fitted to the exhaust and hot air pipes which pass through the bulkhead.

It is claimed that an interchange of the power plant can be carried out in half an hour.

It is interesting to note that provision is made on the bulkhead for a hot air delivery pipe for de-icing nose of wing. (This air is warmed by the exhaust pipe and is drawn through the wing by the proper choice of discharge orifices near the trailing edge, see Air Ministry Translation No. 535.)

*Permissible Amplitudes of Torsional Vibrations in Aircraft Engines.* (F. Masi, J.S.A.E., Vol. 44, No. 4, April, 1939, p. 11.) (67/36 U.S.A.)

Actual computation of the vibratory crankshaft stresses, although a laborious process with many difficulties, should offer the best chance for an intelligent evaluation of the crankshaft torsional vibration characteristics in aircraft engines and of whether the amplitudes are dangerous or within safe limits. In a discussion of various methods used, their relative merits, and allied problems, the author shows that the simple expediency of using fixed allowable amplitude limits, for certain classes of engines, determined from experience, is likely to lead to erroneous conclusions.

A novel method, which has been used on numerous engines by the Naval Bureau of Aeronautics, is suggested. It consists in determining the twist of the crankshaft with the application of rated engine torque and basing the allowable vibration amplitude on the amount of the twist. This method lends itself to rapid routine check of a variety of engines and gives reliable data for conventional designs.

*Present-Day Problems in Accessory Drive.* (R. P. Lansing, J.S.A.E., Vol. 44, No. 4, April, 1939, pp. 12.) (67/37 U.S.A.)

The paper brings out the numerous problems found in the design of accessory power supplies for the larger aeroplanes and the involvements incident to such design, without attempting to forecast their solutions. These problems are primarily the result of the requirements of the long-range plane. It is shown that, in these planes, controls other than flight controls require substantial power to operate them. Landing gears which must be operated are of substantial weight and size, and require considerable power, although in smaller amounts. Radio has many ramifications, such as communications, beam flying, orientation, blind flying, and emergency equipment, all of which necessitate a large increase in power. Pressure cabins also add to the demands for auxiliary power.

Topics discussed are choice of generator drive; accessory drives from main engines; drive by accessory engines; and actuation by electric motor, hydraulics, air pressure, and vacuum.

*Fuel Economy Possibilities of the Otto Cycle Aircraft Engine.* (D. S. Hersey, J.S.A.E., Vol. 44, No. 4, April, 1939, pp. 20.) (67/38 U.S.A.)

Economy of present-day aircraft engines can be improved merely by advancing to spark advance control. The reduction of cruising in-take charge temperatures by the employment of multi-speed superchargers with adequate charge intercooling, also should permit the early use of slightly higher compression ratios.

The author suggests that an engine developed primarily for economy should be able to develop its maximum cruising output at sea level when unboosted and operated at moderate speeds, thus permitting higher compression ratios with further improvement in economy.

The paper outlines the general and economy requirements of existing aircraft engines, and the economy effects of various operating conditions. The factors that affect detonation at both high output and economy conditions, as well as the compromises necessary to avoid detonation, are considered in some detail.

*Present Prospects for Use of Safety Fuels in Spark Ignition Engines.* (F. C. Mock, J.S.A.E., Vol. 44, No. 4, April, 1939, pp. 21-2.) (67/39 U.S.A.)

Recent developments in fuel refining have developed new safety fuels, with a flash point of about 105°F., distillation range 375-475°F. and about 87 octane rating.

Three methods of fuel feed are discussed:—

(1) Injection into the cylinder.
(2) ,, ,, intake pipe.
(3) ,, ,, supercharger.

Detailed problems discussed cover:—

(1) Injection equipment.
(2) Change in engine and cylinder required.
(3) Fuel/air metering and power control.
(4) Starting.
(5) Installation.

It appears that over 60 per cent. of the German aircraft engines are now using fuel injection. Quite apart from better distribution, fuel injection equipment can burn a wider range of fuels and this may be another reason for the German choice.

*Characteristics of Magnetically Actuated Fuel Injection Valve.* (C. J. Vogt and T. A. Rogers, Autom. Ind., Vol. 80, No. 16, 22/4/39, pp. 530-6.) (67/40 U.S.A.)

The magnetically actuated spray valve offers a means of accurately controlling the quantity of fuel injected per cycle. It will accurately meter smaller quantities than is possible with any mechanical system. Successive sprays are reproducible, which is a large factor in smooth engine operation. Control of the character of the spray by simple changes in the electrical circuit has great possibilities.

Governing of injection delay offers no complex problems, since the system is independent of the dynamics of the pump and the fuel column.

*Effect of Air Movement on Combustion Rates in Spark Ignition Engines.* (A. M. Rothrock, J. Aeron. Sci., Vol. 6, No. 6, April, 1939, pp. 273-277.) (67/41 U.S.A.)

In the case of spark ignition engines, the air movement is produced during the induction stroke and persists to a considerable degree through the compression stroke and in some cases through the expansion stroke.

The air movement may be of the swirl type (regular rotation) or turbulent (irregular movement on either a large or small scale).

The air movement produced by changes in the masking of the inlet valve was studied experimentally both under motoring and firing conditions. In the former case the engine was provided with a glass cylinder and the air currents (rendered visible by means of small feathers) were photographed (2,000 frames a second).

The firing experiments were carried out on a different engine (same shape combustion head) fitted with a glass window in the head and using the Schlieren method.

The principal conclusion reached is that an increase in the velocity of the incoming air does not necessarily increase the rate of combustion. Valve arrangements giving maximum turbulence generally produced longer combustion times than arrangements producing a mixture of swirl and turbulence.

It thus appears that the well known reduction of combustion time with speed of engine operation cannot be accounted for solely by an increase in turbulence.

*Stress Analysis for Leading Edge Wing Spars.* (J. S. Newell, J.S.A.E., Vol. 44, No. 4, April, 1939, p. 22.) (67/42 U.S.A.)

Wing beams having a single shear web, located at about 30 per cent. of the wing chord, plus a stress carrying sheet running around the leading edge, are in most cases unsymmetrical sections and should be analysed as such. Because of the thinness of the shear-carrying elements, special care is required in determining the distribution of the shear stresses around the cross-section.

The internal shear stresses acting upon each unit area in the cross-section are shown to result in forces that tend to twist the beam, unless there is coincidence of the lines of action of the resultants of the internal shear forces and of the external forces producing shear on the cross-section. For this reason it is imperative that means be provided for determining the " shear centre " or " centre of twist " of the beam so that the magnitudes of such torsional couples may be evaluated. The author provides these means in the form of formulæ, and presents an example to illustrate their use.

*Physical Properties of Synthetic Resin Materials.* (M. Fishbein, N.A.C.A. Tech. Note No. 694, March, 1939.) (67/43 U.S.A.)

A study was made to determine the physical properties of synthetic resins having paper, canvas, and linen reinforcements, and of laminated wood impregnated with a resin varnish.

The results show that commercial resins have moduli of elasticity that are too low for structural considerations. Nevertheless, plastics exist that have favourable mechanical properties and, with further development, it should be possible to produce resin products that compare favourably with the light metal alloys.

The results obtained from tests on Compound 1,840, resin impregnated wood, show that this material can stand on its own merit by virtue of a compressive strength four times that of the natural wood. This increase in compressive strength was accomplished with an increase of density to a value slightly below three times the normal value and corrected one of the most serious defects of the natural product.

CONCLUSIONS.

The future of plastics and wood impregnated with resins depends to a great extent upon the impetus which the aircraft industry, in co-operation with the manufacturers of these products, is willing to give to experiments and to the development of these materials from considerations of improved mechanical strength. For plastics to be active competitors of the present light alloys, they must be improved to the point where they have well-defined physical properties and, in the case of wood, the heterogeneous character of the material must be changed to one that approaches homogeneity.

*Torsional Stability of Aluminium Alloy Seamless Tubing.* (R. L. Moore and D. A. Paul, N.A.C.A. Tech. Note No. 696, March, 1939.) (67/44 U.S.A.)

The results of these torsion tests on several different sizes of 51 ST seamless round tubing may be summarised as follows:—

1. The maximum shearing stresses developed in the tubes having $D/t$ ratios of 77, 104 and 139, for lengths equal to the diameter, were computed to be 21,800, 19,200 and 18,400 pounds per square inch, respectively. For lengths of 40 times the diameter in the same size of tubing, the corresponding maximum shearing stresses were 10,400, 7,500 and 4,800 pounds per square inch, respectively.

2. Elastic instability failures were apparently obtained in all the tubes tested having lengths greater than two to six times the diameter. For shorter lengths, failures resulted from a combination of yielding of the material in shear and buckling.

3. The torsional strengths developed in the tubes that failed elastically were, in most cases, within 10 per cent. of the values indicated by the theories of Donnell, Timoskenko and Sturm, assuming a condition of simply supported ends.

4. Sturm's theory indicated critical shearing strengths below those of Donnell in all cases, but in close agreement with those of Timoshenko in the long-tube range. The test values were found to lie for the most part within the limits indicated by the different theories.

5. Although some end fixity was undoubtedly obtained in the tests, the unknown degree to which this effect was compensated for by out-of-roundness in the tubes and eccentricities of loading makes it difficult to differentiate between the accuracy of the different theories.

*The Frequency of Torsional Vibration on a Tapered Beam.* (R. P. Coleman, N.A.C.A. Tech. Note No. 697, March, 1939.) (67/45 U.S.A.)

A solution for the equation of torsional vibration of tapered beams has been found in terms of Bessel functions for beams satisfying the following conditions: (*a*) The cross sections along the span are similar in shape; and (*b*) the torsional stiffness of a section can be expressed as a power of a linear function of distance along the span. The method of applying the analysis to actual cases has been described. Charts are given from which numerical values can be immediately obtained for most cases of practical importance. The theoretical values of the frequency ratio have been experimentally checked on five beams having different amounts of taper.

*Metal Sprayed Bearings. Their Use for High Speed Operations.* (H. Shaw, Metal Industry, 14/4/39, pp. 415-8. Metropolitan Vickers Technical News Bulletin, No. 657, 21/4/39, p. 1.) (67/46 Great Britain.)

Tests have been made on a wide range of bearing metals built up by metal spraying as against the same metals cast. The test pieces included sprayed metal from France, Germany and America. Friction and seizure load tests were run at speeds of 50, 1,000 and 3,000 ft./min. on babbit, and sprayed babbitt, using plain and graphited lubricating oils. A similar test on lead bronze bearings was performed, and the results indicated that the use of sprayed metal gave lower friction and higher seizure loads. Other materials including cadmium-nickel, cadmium-nickel-silver, and cadmium-silver-copper were tested especially with respect to their tendency to crack under impulsive loading. The influence of colloidal graphite is discussed.

Illustrated with two tables and two graphs.

*The Elastic Theory of Wood Failure.* (C. B. Norris, Trans. A.S.M.E., Vol. 61, No. 3, April, 1939, pp. 259-261.) (67/47 U.S.A.)

This paper deals with various theories advanced for the failure of wood. The formulæ developed by Jacoby, Howe and Hankinson for expressing the crushing strength of wood are examined and their relative practical value indicated. Of the three the Hankinson formula, while being strictly empirical, agrees with experimental results better than the others. The author then proceeds to outline the steps of derivation of Hankinson's formula, applying the theory of failure advanced by Hencky. A second theory is analysed which also leads to Hankinson's formula. The author points out that the methods used in deriving Hankinson's formula are very approximate, but that such a formula is better than none.

*Fully Automatic Riveting in Light Metal Aircraft Construction.* (W. Pleines, Inter. Avia., No. 638, 25th April, 1939, pp. 1-3, and Inter. Avia., No. 637, 21st April, 1939, pp. 1-3.) (67/48 Germany.)

After pointing out that welded joints are not as strong as rivets, the author describes a new automatic riveting machine originally developed by the Henschel Aircraft Works and which is now on sale.

1. During the process of making a rivet joint the work was not displaced; all operations, drilling, countersinking (with cutting detachment), insertion of rivet, possibly dimpling of the hole borders, driving and heading of rivet, are effected automatically by one single engagement of the machine; they take place in a vertical axis to enable also curved parts to be machine riveted.

2. The holes are drilled in order to obtain maximum smoothness of the hole walls (advantage over stamping, elimination of hair cracks in the light alloys which, as is well known, are particularly liable to notching) and, eventually, to countersink with removal of chips simultaneously with the drilling by means of special countersink drills. The chips generated on both sides of the work, *i.e.*, the entry and exit sides of the drill, are removed by compressed air.

*Arc Welding with Special Reference to the Welding of High Alloy Steels and Non-Ferrous Metals.* (F. Womaczka, Elektrotechnik und Maschinenbau, 31/3/39, pp. 178-189. Metropolitan Vickers Tech. News Bulletin, No. 658, 28/4/39, p. 8.) (67/49 Germany.)

The author discusses those special problems of the technique of arc welding which are set by the nature of the material. In particular he considers the welding of thin sheet, of high carbon steels and steels which are difficult to weld, of high alloy steels, and of non-ferrous metals, including aluminium and copper as well as their chief alloys. He gives a number of tables, for example, one showing the thicknesses of sheet which can be welded by various types of joint, another giving the strength properties of butt welds on 12 mm. sheet; two others give figures for notch impact strength and fatigue bending strength for 12 and 6 mm. sheet. Illustrated with 14 photographs.

*Riveting Machines and Light Alloy Rivets.* (C. Harris, Light Metals, Vol. 2, No. 15, April, 1939, p. 133.) (67/50 Great Britain.)

After dealing with a representative type of solid riveter the author discusses the advantages of employing tubular or semi-tubular rivets for certain kinds of work. Although much more expensive, the tubular rivet possesses many advantages mainly due to the greater ease of control during setting. The elimination of excess metal in the rivet shank reduces the relatively heavy working required when heading a solid rivet.

No diminution of the shear strength is occasioned, the tubular type ensuring a perfectly tight fit in the hole.

Examples of high speed rivet setting machines for tubular rivets are described. It is stated that the setting of the rivets is rather quicker than spot welding.

*The Use of Symmetric and Anti-Symmetric Loadings.* (J. S. Newell, J. Aeron. Sci., Vol. 6, No. 6, April, 1939, pp. 235-239.) (67/51 U.S.A.)

The stressing of statistically indeterminate structure becomes relatively easy if the structure is symmetrical and the load applied symmetrically. Now the advantage of symmetry may be had on any symmetrical structure, by substituting two or more equivalent force systems for the original unsymmetrical loading.

In the usual case, two systems suffice. One system has all forces and reactions symmetrically disposed about the plane of symmetry, the second has them arranged anti-symmetrically, *i.e.*, force having components acting towards plane of symmetry or upwards on the right, have counterparts in the opposite direction on the left, etc.

Under such loadings relationships exist involving not only forces and moments, but also slopes and deflections. As a result 12 general equations of conditions can be established which are very useful in the rapid analysis of the structure.

The author illustrates the application of the method by means of two worked out examples.

*Measurement of Stiffener Stresses and Effective Widths in Stiffened Panels.* (H. B. Dickinson and J. R. Fischel, J. Aeron. Sci., Vol. 6, No. 6, April, 1939, pp. 249-54.) (67/52 U.S.A.)

In the design of a stressed skin metal aeroplane it is essential that correct stiffener stresses and effective widths of skin acting with the stiffener be known in order to ensure that fictitious margins of safety in wing and fuselage analyses are not shown. In this paper the problem of determining these stresses and effective widths is discussed and some experimental results from Lockheed tests are presented. An experimental method is described which makes possible the accurate determination of these quantities, employing extensometer strain data interpreted by means of a compression stress-strain curve for the stiffener.

*The Application of Thermostatic Bimetals.* (P. A. Morgan, Mech. World, 7/4/39, pp. 339-41. Metropolitan Vickers Tech. News Bulletin, No. 656, 14/4/39, p. 1.) (67/53 U.S.A.)

After describing the various forms in which thermostatic bimetallic strips are produced, and their application to apparatus of different types, it is shown that a thin strip produces a greater deflection than a thicker element, but develops less power to actuate any device depending on its movement. The power can be increased by using a wider strip and the deflection by increasing the length. The design of a suitable element is a compromise between these factors. Examples are given of the use of bimetallic elements, applications mentioned including a vertical stem type dial thermometer a thermostatic mixing valve, automatic reset and manual reset motor protection thermostats, and a thermostatically controlled gas jet.

Illustrated with six photographs.

*Air Line Power Control with a Torque Meter.* (W. G. Lundquist, J.S.A.E., Vol. 44, No. 4, April, 1939, p. 20.) (67/54 U.S.A.)

In this paper the author presents an impartial discussion on the possible benefits to airline operators of using torque meters. He points out that the long-range operator is the only one who probably will realise any appreciable improvement in operating efficiency by the use of the torque meter, and even he must survey carefully his present operations to ascertain whether or not he already is operating so near to maximum efficiency that the application of the

torque meter will not produce any benefits. The torque meter will add from 10 to 50lb. to an engine, including the indicating equipment.

The mechanical features of some current torque meter types are reviewed.

*Correlation of Aircraft and Ground Station Altimeters.* (R. D. Kelly and H. F. Salisbury, J. Aeron. Sci., Vol. 6, No. 6, April, 1939, pp. 240-272.) (67/55 U.S.A.)

The errors treated by the author come under the following five headings:—

(1) Errors in the basic standard instrument (usually a mercury barometer).
(2) Errors in calibration, temperature, friction, balance, etc., of aircraft instruments.
(3) Personal errors.
(4) Installation errors.
(5) Incorrect or non-uniform ground station elevation.

In order to determine and control the actual existing spread of altimeter readings, a record is kept by United Air Lines for one day every month of the indications of the flight altimeter readings of planes located at a series of stations.

*The Theory of Diaphragm Pressure Recorders.* (A. Moller, Forschung, Vol. 10, No. 2, March-April, 1939, pp. 80-87.) (67/56 Germany.)

The author considers the case of a thin circular diaphragm, clamped at the edges and undergoing a relatively large deflection when subjected to a pressure difference, one side of the diaphragm being sealed (capsule). Equations are developed for correlating the deflection with changes in the electrical capacity of the system and thus rendering an electrical method of recording possible.

The zero position of the membrane of a sealed capsule naturally depends on the atmospheric pressure, but this effect can be allowed for by having a double capsule, the second being in communication with the atmosphere.

The method of calibrating capsules of this type is described and examples of pressure records are given.

*Diffraction and Refraction of a Horizontally Polarised Electro-Magnetic Wave Over a Spherical Earth.* (M. C. Gray, Phil. Mag., Vol. 27, No. 183, April, 1939, pp. 421-436.) (67/57 Great Britain.)

Formulas are derived for the electro-magnetic field at a point on or above the surface of a spherical earth due to the presence of a vertical magnetic dipole. It is shown that the resultant field resembles that due to a vertical electric dipole above a spherical earth of low conductivity, and that in the magnetic case the values of the earth constants are of much less importance than in the electric. Curves are included showing the variation of the field with distance and height.

*Improvements in the Lorenz Blind Landing System.* (Inter. Avia., No. 639, 28/4/39, p. 7.) (67/58 Germany.)

Tests with an improved Lorenz glide-path installation have been conducted already in September, 1938. These tests have now been resumed. It has been possible to improve considerably, by the use of the new installation, the blind-landing system employed, the following having been achieved by very simple means:—(1) the approach path now follows an entirely straight line from the beginning of the glide path (outer marker signal) down to the ground, as a result of which the machine is able to fly at a constant rate of descent. (2) The touching down point of the straight glide-path may be fixed at any desired distance from the airfield boundary. The glide-path installation operates with a 100-watt transmitter (at present 35.8 mc.) which, seen from the homing transmitter, is located about 1,640ft. (500 m.) laterally of the landing direction. A special receiver is

provided in the aircraft which operates the available visual indicating device. A landing installation built for Fort Worth, Texas, by the Lorenz Company, now being installed, also makes use of the new glide-path principle though it works, corresponding to American requirements, on a frequency of about 94 mc.

*Boiling Heat Transfer in Natural Convection Evaporators.* (G. A. Atkin and W. H. McAdams, Ind. and Eng. Chem (Industrial Edition), Vol. 31, No. 4, April, 1939, pp. 487-91.) (67/59 U.S.A.)

1. With distilled water boiling at atmospheric pressure on horizontal nickel-plated or chromium-plated tubes, the maximum flux was approximately the same (350,000 B.T.U. per hour per square foot) whether a single-tube or a sixty-tube apparatus was used. City water boiling on a sealed tube gave approximately the same maximum flux at a higher temperature difference.

2. Under similar conditions three paraffin alcohols (isopropyl, isobutyl, and n-butyl) gave only 30 per cent. as much maximum flux as distilled water, and required higher temperature differences.

3. At a given temperature difference, the effect of vacuum in reducing the flux is not so large in the range of high flux as that reported by others who used low flux.

4. Further work is needed to study the effects of a number of factors, such as pressure, nature of the surface, nature of the liquid, and variations in temperature with position on the tube.

*N.A.C.A. 24th Annual Report*, 1938. (67/60 U.S.A.)

During the period under review, the N.A.C.A. have issued 33 Reports, 51 Notes and 39 Tech. Memo. (Translations).

The total expenditure over the year amounted to approximately 2 million dollars, roughly half of which was utilised for personnel services.

Printing and binding accounted for 21,000 dollars.

The following are extracts from the concluding statement of the Report:—

Air power is primarily dependent not only upon numbers of aeroplanes, but the aeroplanes themselves must have performances at least equal to that of an enemy.

The fact that modern military aircraft requires frequent replacement by improved types brings forcibly to our attention the necessity of basing their design upon the best and most reliable data from research laboratories.

Unless our own laboratories keep pace, the U.S. cannot hope to compete with foreign nations in the development of either military or commercial aircraft.

The U.S. for a number of years have held undisputed leadership in the field of aeronautical research. At the present time that leadership is being challenged. Unless therefore we fully recognise the challenge and make provisions for extending the Committee's research facilities and for increasing the number of trained research personnel, the U.S. will definitely fall behind.

*Methods of Clearing Aerodromes of Fog.* (Les Ailes, Vol. 19, No. 931, 20/4/39, p. 8.) (67/61 France.)

Two possible methods exist for clearing a limited space of fog. One method is thermal, the other chemical.

The thermal method has so far only been tried in the form of heat (British tests with coke fires arranged along the contours of the landing ground).

As an alternative the author suggests fitting refrigerating plant below the runway and thus preventing the lower atmospheric layers from becoming saturated with water vapour.

It is claimed that a relative small decrease in air temperature will prevent the notorious " dissolving views " so dangerous during landing.

In the chemical method, calcium chloride is usually applied for absorbing the moisture vapour. In the scheme proposed by the author, the runway is in the

form of a grid, the chemical being carried on a moving belt below the surface. The spent chemical is dehydrated in a special plant and stored for further use.

By applying both refrigeration and chemical water absorption, it should be possible to clear the fog up to an altitude of 30-40 m.

*Experiments on the Thermal Radiation of Flames.* (J. Werneburg, Forschung, Vol. 10, No. 2, March-April, 1939, pp. 61-79.) (67/62 Germany.)

Measurements on the radiation of flames have so far been limited to fixed positions perpendicular to the flame axis, the radiation being assumed to be constant in all directions. The author amplified these results by investigating both the distribution in space as well as the variation in intensity over the surface of hydrogen and coal gas flames. Whilst the radiation is not strictly equal in all directions, the total radiation can be calculated with sufficient accuracy from data based on normal emission.

The variation in the intensity of the radiation over the surface of the flame is appreciable, maximum values being usually obtained in the neighbourhood of the inner cone. It appears that in an ordinary welding process, the heat transmission by radiation may amount to between six and 25 per cent. of the total, depending on the scrubbing speed of the gas.

## LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the supply of copies of translations mentioned below should be addressed to the Under-Secretary of State (R.T.P.), Berkeley Square House, W.1, and will be supplied, free of charge, as far as availability of stocks permit. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

| TRANSLATION NUMBER AND AUTHOR. | TITLE AND JOURNAL. |
|---|---|
| | AERODYNAMICS AND HYDRODYNAMICS. |
| 866 Frankl, F. ... ... Voishel, V. ... ... | *Turbulent Friction in the Boundary Layer of a Flat Plate in a Two-Dimensional Flow of Compressible Gas at High Speeds.* (Trans. C.A.H.I. Moscow Report No. 321, 1937.) |
| 868 Kiel, G. ... ... | *The Measurement of True (Undisturbed) Static and Dynamic Pressures in Flight.* (L.F.F., Vol. 15, No. 12, 20/12/38, pp. 583-97.) |
| 870 Flugge-Lotz, I. ... Kuchemann, D. ... | *Summarised Report on Measurement of Downwash with and without Slipstream.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 172-93.) |
| 887 Stsielard, K. S. ... | *Measurement of the Drag of Wing Profiles in the C.A.H.I. High Speed Wind Tunnel.* (Trans. All-Union Conference on High Speed Aircraft, Moscow, 1936, pp. 92-7.) |
| | AIRCRAFT. |
| 874 Voigt, H. ... ... | *Further Experiments on Wing Vibrations.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 249-58.) |
| 882 Ritter, E. ... ... | *Collaboration Between the Aircraft Designer and the Production Engineer.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 482-90.) |

| TRANSLATION NUMBER AND AUTHOR. | TITLE AND JOURNAL. |
|---|---|
| 884 Freise, H. ... ... | *Peak Values and Frequency Loads Due to Gusts on Commercial Aircraft.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 289-302.) |
| | MATERIALS AND ELASTICITY. |
| 869 Kromm, A. ... ... | *The Stability of a Curved Metal Sheet Under the Action of Shearing and Longitudinal Forces.* (L.F.F., Vol. 15, No. 10-11, 10/10/38, pp. 517-26.) |
| 872 Kuch, W. ... ... | *New Investigation on the Use of Hardening Plastic Masses in Aircraft Construction.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 561-73.) |
| 873 Rethel, W. ... ... | *Shell Construction with Longitudinal Panels.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 491-4.) |
| 876 Marguerre, K. ... | *On the Collapse Force of a Slightly Curved Beam.* (Sitzungsberichten der Berliner Mathematischen Gesellschaft, Vol. 37, pp. 22-40.) |
| | INSTRUMENTS. |
| 867 Kampé de Feriét, J.... Rollin, G. ... ... | *Static Pressure Indicator. Description of the Indicator Calibration.* (G.R.A. Tech. Note, No. 1, 1939.) |
| 878 Klein, G. ... ... | *Importance of Automatic Steering in Aircraft.* (Collected Papers of the Lilienthal Society, 1938, pp. 237-42.) |
| 879 Fischel, E. ... ... | *The Principles and Constituent Elements of Automatic Steering Apparatus for Aircraft.* (Collected Papers of the Lilienthal Society, 1938, pp. 231-6.) |
| 880 Wilde, R. ... ... | *Some Recent Work on the Problem of Automatic Control.* (Collected Papers of the Lilienthal Society, 1938, pp. 243-7.) |
| | THEORY AND PRACTICE OF WARFARE. |
| 809 Golishev ... ... | *Determination of Firing Range.* (Air Fleet News, U.S.S.R., Vol. 20, No. 6, June, 1938, pp. 46-7.) |
| 875 Shelimov, N. ... | *Method for Training Air Force Staffs in Liaison Work.* (Air Fleet News, U.S.S.R., Vol. 20, No. 4, April, 1938, pp. 70-3.) |
| 877 Incerpi, P. ... ... | *Ground Attack in the Spanish Aerial War.* (Rivista Aeronautica, Vol. 14, No. 8, August, 1938, pp. 257-65.) |
| 881 Barone, U. ... ... | *Camouflage Applied to Aircraft in Flight and on the Ground.* (Rivista Aeronautica, Vol. 14, No. 8, August, 1938, pp. 303-10.) |
| | PHYSIOLOGY. |
| 883 Strughold, H. ... | *The Time Reserve of Human Beings After the Interruption of the Oxygen Supply at High Altitudes.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 3, pp. 84-8.) |

# REVIEWS.

PHYSICAL AND DYNAMICAL METEOROLOGY.

By Professor D. Brunt, M.A., B.Sc. Published by the Cambridge University Press. Price 25s.

This is the second edition of this book, and it differs from the first edition in that a few portions, now considered unimportant, have been omitted while a number of other chapters have received additions. One chapter, that dealing with atmospheric turbulence, has been completely re-arranged.

The book is intended to provide a text book on its subject for the use of post-graduate students and is consequently of little use to the reader who may wish to know whether it is going to rain to-morrow. The author takes the obviously correct view that meteorology should aim at being a metric science, and he has rightly used equations wherever necessary. Of the book itself it is sufficient to say that it is written in clear English, which leaves no doubt about the author's meaning, that the diagrams are excellent and that the references to other work are copious and conveniently arranged, and that it is a model of what a text book of this type should be. There is one small point. Cannot the meteorologists agree on the best temperature scale to use for their particular work, and, having done so, agree to scrap all the others?

There is no doubt that meteorology is slowly but successfully grappling with its difficulties and that the mathematical means which have been developed, as is illustrated in this book, have been successful in shedding light on many details, but even to-day there is no explanation for the origin, maintenance, travel and death of cyclones and anticyclones, and the reasons why variations of pressure are produced over large areas of the earth's surface are still unknown.

The immense difficulties of the subject are added to by the absence of data, especially over the areas of the earth occupied by water, and it is on the acquisition of further information of this nature that meteorology must largely depend for its future progress, and this, again, must depend on government assistance. The science is at present in the position of collecting facts and of explaining them mathematically, and when this process has progressed sufficiently it should be possible to produce that broad generalisation of the whole problem which will eventually illuminate many dark corners. There is no man more qualified to do this than Professor Brunt when the necessary information and data have been collected.

PROPERTIES AND STRENGTH OF MATERIALS.

By J. A. Cormack, B.Sc., A.R.T.C. Published by Macmillan and Co., Ltd. Price 8/6.

This book is described on the dust cover as an elementary textbook for students of engineering, and in the preface as an attempt to present the subject of Strength of Materials in such a way as to carry conviction to practical-minded readers. I consider that it carries out this object very well. It is quite comprehensive in its general scope, as, in addition to the usual subjects, non-metallic materials such as concrete are discussed and there are even some notes on plastics. There is also a chapter on materials themselves, describing the peculiarities of the different ferrous materials from wrought iron to alloy steel, and also the various brasses and bronzes. Aluminium and its alloys are also discussed.

The general treatment is chosen so as to avoid the use of calculus, but in certain cases calculus proofs are given as footnotes. It is unfortunate that there is no bibliography, for it is especially important that a book which has been written for the purpose of interesting the elementary student in such a subject should also tell him where to obtain the greater knowledge which it is hoped that he will want. Apart from this point, the book should attain its goal, as it is well written and requires only an elementary knowledge of mathematics to be understood.

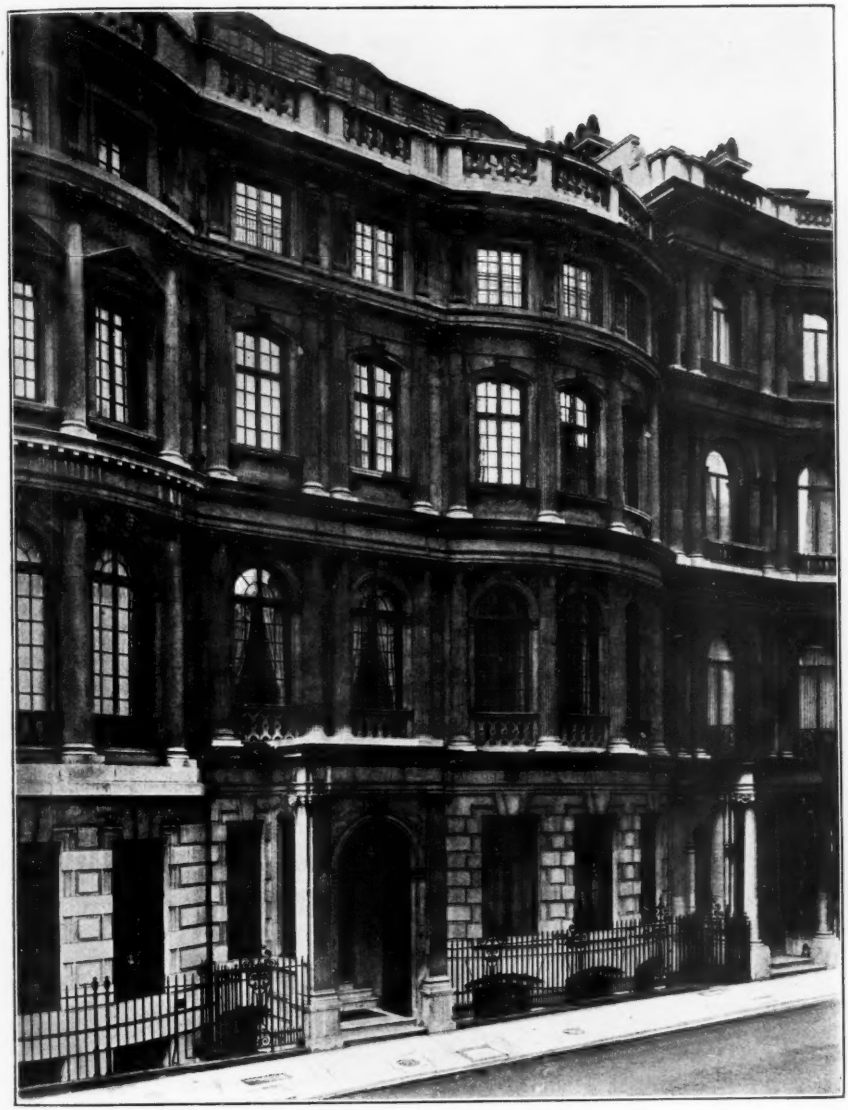


FIG. 1.

*No. 4, Hamilton Place, W.1.*
*Exterior view from the front.*

# THE NEW HOME

OF THE

# ROYAL AERONAUTICAL SOCIETY.

The Royal Aeronautical Society was founded on January 12th, 1866.

The following are extracts from a meeting held on that date at Argyll Lodge, Campden Hill, His Grace the Duke of Argyll in the chair.

" Resolved that it is desirable to form a Society for the purpose of increasing by experiments our knowledge of Aeronautics and for other purposes incidental thereto, and that a Society be now formed under the title of the ' Aeronautical Society of Great Britain,' to be supported by annual subscriptions and donations."

" Resolved that the following noblemen and Gentlemen be requested to act respectively as President, Vice Presidents, Treasurer and Honorary Secretary of the Council; and that the Council do consist of the following, viz. :—

*President*—His Grace the Duke of Argyll; *Vice Presidents*—His Grace the Duke of Sutherland and Lord Richard Grosvenor, M.P., F.R.G.S.; *Treasurer*—James Glaisher, Esq., F.R.S., F.R.A.S.; *Honorary Secretary*—Fred. W. Brearey, Esq. Sir Charles Bright, M.P., James Wm. Butler, Esq., Hugh W. Diamond, Esq., M.D., F.S.A., William Fairbairn, Esq., Ll.D., F.R.S., John Lee, Esq., Ll.D., F.R.S., etc., Magnus Ohren, Esq., A.I.E.E., F. H. Wenham, Esq., M.M.S., H. F. Westcar, Esq., Royal Horse Guards—with power to add to their number; and that Messrs. Matthews and Greethams' offer to act as Honorary Solicitors be accepted with thanks."

" Resolved that the Prospectus now before us do form the basis of the Society."

" Resolved that the Honorary Secretary be requested to take steps to procure subscriptions and donations, in accordance with the terms of the Prospectus, and to pay the amounts from time to time to the Treasurer; and that the Treasurer be authorised to disburse such expenses as may be necessary for that purpose up to (£10) ten pounds, and any other expenses which may have been incurred not exceeding (£10) ten pounds."

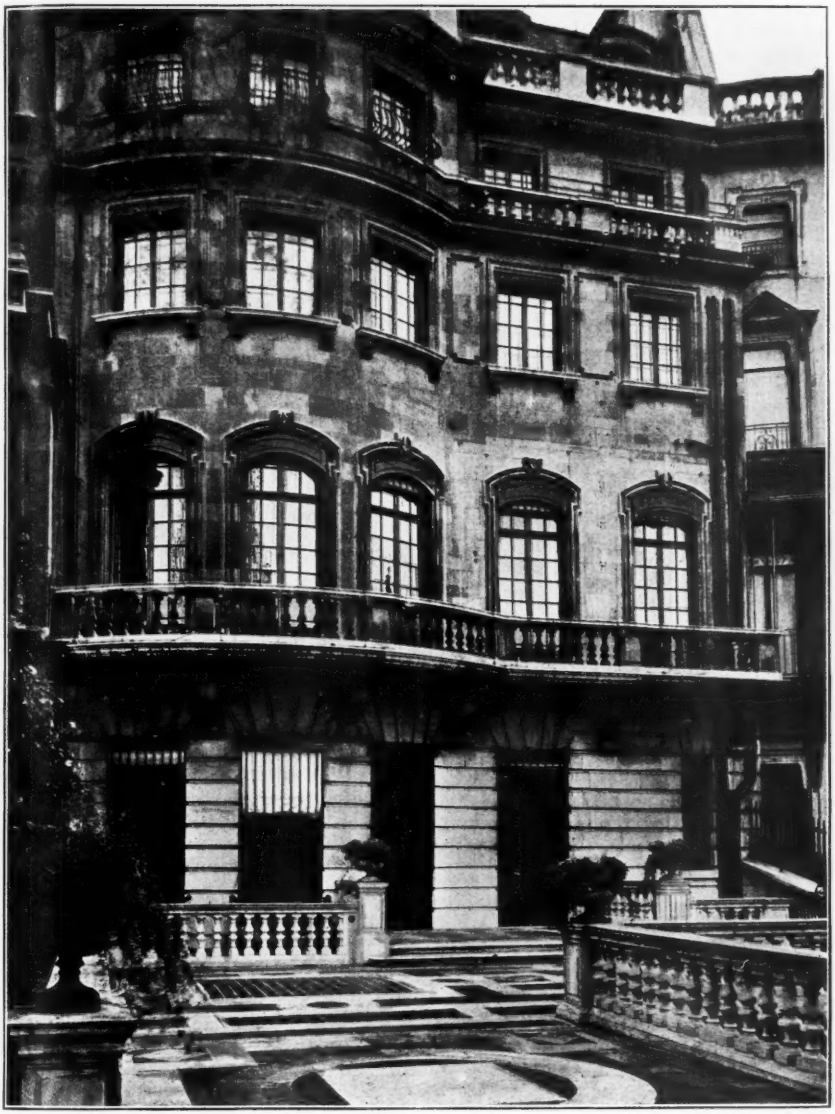
" Resolved that the following Gentlemen be deputed a Sub-Committee to draw up the Rules of the Society, viz., Mr. Wenham, Mr. Glaisher and Mr. Brearey."

" Resolved that the adjourned meeting of the Council be held in one month hence at Argyll Lodge."

(Signed) SUTHERLAND.

The second meeting was held on February 12th, 1866 and the third on February 28th, 1866. At this meeting it was reported that the Patent Office had presented the Society with copies of all aeronautical patents since 1815. (These patents have been presented ever since and the Society has now the largest collection of British aeronautical patents outside official sources.)

With the Duke of Argyll as first President, the Duke of Sutherland, Lord Richard Grosvenor, and Lord Dufferin as Vice Presidents, and Sir Charles Bright, M.P., F.R.A.S., William Fairbairn, Ll.D., F.R.S., Hatton Turnor, author of the famous work " Astra Castra," James Glaisher, F.R.S., F.R.A.S., and F. H. Wenham, among the Members of the Council, the Society had the cachet of the scientific world. F. W. Brearey acted as Honorary Secretary and to him the Society owes the greatest debt of all, for he kept the Society alive when it often looked to be " in extremis."



*Courtesy of "The Aeroplane."*

FIG. 2.

*No. 4, Hamilton Place, W.1.*
*Exterior view from the back.*

Although founded in the days when balloons were the only method of getting into the air, it is significant that from its earliest days leading members of the Society were convinced of the coming of the heavier-than-air machine, and bent all their energies towards the successful solution of the problem. It is of interest to note that the Duke of Sutherland offered a prize of £100 in 1866 for a flight from the top of Stafford House!

Wenham, Thomas Moy and others undertook, in those early days, on the Society's behalf, a series of aerodynamic experiments, made with inclined planes in a primitive form of wind tunnel, which were among the earliest investigations of that time.

In 1868 the Society held the first Aeronautical Exhibition at the Crystal Palace.

We are not concerned here with the many famous people who became members of the Society. Its history has been published and a short account is given in the "Aims and Objects of the Society," which is available free of charge to anyone interested.

It is sufficient to mention at random here such men as Glaisher, Stringfellow, Lilienthal, Pilcher, Maxim, Horatio Phillips, Sir William Crookes and Orville Wright.

The early meetings of Council were held at Argyll Lodge, Campden Hill, at Stafford House, at the house of Mr. Glaisher, the famous balloonist, and at other houses in London as circumstances allowed. From the early days, however, meetings of members were held at the Royal Society of Arts, a custom which remained for nearly 70 years. The offices of the Society were at the private addresses of Fred. Brearey, Hon. Secretary, at Blackheath, and his successor Eric Bruce, Hon. Secretary, at Kensington.

It was not until 1902 that the Society had offices of its own. The following is an extract from the Council Minutes dated December 4th, 1902:—

> "The Hon. Secretary informed the Council that he had been able to secure a room at 53, Victoria Street, Westminster, for the office and library of the Society, at a rental of £20 per annum."

The impetus given to the activities of the Society by the growing interest in aviation carried it on until 1911. In that year the organisation of the Society underwent a drastic revision. A new constitution was formulated in order to enable the Society to function in response to the growth of aeronautical science and technology, and the Society entered on the most significant era in its history—an era synonymous with the age-long delayed achievement of mechanical flight.

In 1911 a move was made to 11, Adam Street, Adelphi, and there "on Monday evenings, from 5 o'clock, informal discussions on aeronautical subjects were held."

The Annual Council Report of 1917 stated:—

> "It had been fully realised for a long time past that the rooms of the Society in Adam Street were totally inadequate for the Society, but the funds of the Society did not justify the expenditure necessary for adequate accommodation. Owing, however, to careful expenditure in the past and to a considerable increase in membership, the Council decided early in the year that the Society could now afford suitable premises, and were fortunate enough to obtain a lease of the offices in 7, Albemarle Street."

There, until March, 1939, the Society remained. In those 22 years it went through many vicissitudes. During the last seven years of its tenancy the Council were again faced with the problem that the Society's headquarters were inadequate for the rapidly growing expansion which was taking place in all aeronautical activities. As in the case of the move to 7, Albemarle Street, however, the problem of finance proved an obstacle. The move to 7, Albemarle Street was only made as a result of the generosity of certain members providing new furniture and paying all the necessary moving expenses.

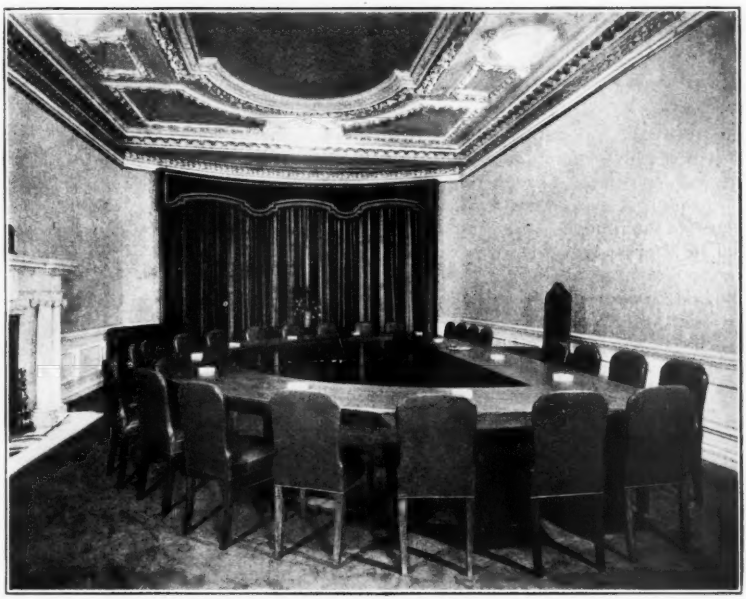


FIG. 3.
*No. 4, Hamilton Place.*
*Part of the Council Room, showing the D-shaped Council table.*

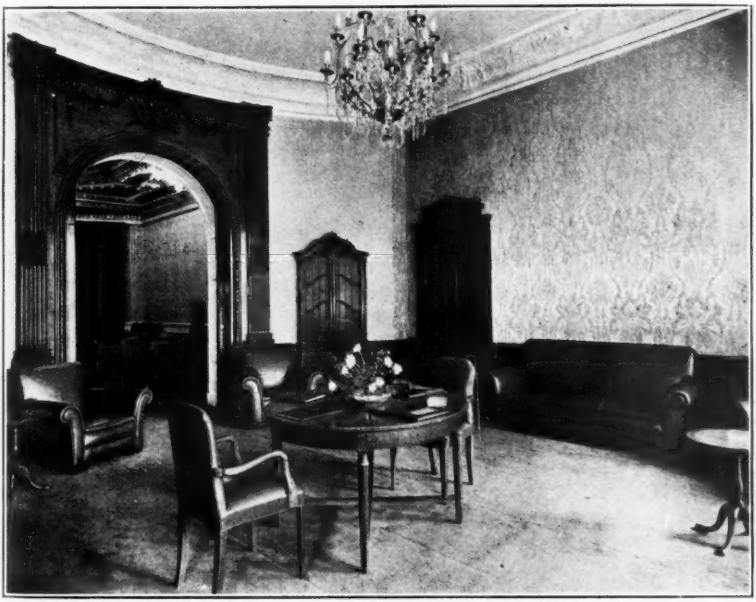


FIG. 4.
*No. 4, Hamilton Place.*
*Part of the Members' Reading Room, looking through the sliding doors towards the Council Room.*

It was early realised by the Council that very much larger premises than 7, Albemarle Street would be required and a correspondingly larger sum to allow for the proper furnishing and upkeep of the house.

Thanks to the splendid response of many members of the Society and firms in the industry, the Council, in October, 1938, obtained an option on No. 4, Hamilton Place, and, at the end of March, 1939, moved from No. 7, Albemarle Street.

No. 4, Hamilton Place is situated at the Hyde Park Corner end of Park Lane.

A special committee was formed, charged with the duty of carrying out the necessary alterations and furnishing the new premises in keeping with the dignity of the Society, the beauty of the house, and its practical utility for offices. The Committee appointed Colonel Abbott, F.R.I.B.A., to advise them on the structural alterations, and Mr. H. C. Bradshaw, F.R.I.B.A., to advise them on the furnishing. The result has been a harmonious whole which gives a unique atmosphere to the new offices of the Society.

*Courtesy of "Flight."*

FIG. 5.

*Close-up of the gold embossed badge on the President's chair.*

The furnishings throughout are in mahogany and walnut. All the furniture was specially designed and the carpets, curtains and fittings chosen to harmonise with the furniture.

Fig. 1 shows the exterior front view of the new offices. It is a five-storey building, close to Hyde Park Corner.

The back of the building overlooks Hamilton Gardens and Hyde Park, and from the top storey is obtained one of the most magnificent views in London.

The ground floor contains the Council Room, Members' Reading Room and Waiting Room. The walls of the Council Room and the Members' Reading Room are lined with gold coloured tapestry. The Council table is a unique D-shaped table, made of mahogany, and specially designed so that every speaker can be seen and heard clearly from any seat at the table. The Presidential chair is embossed with the Society's crest in gold.

The Members Reading Room looks out on the terrace and Hamilton Gardens. Between it and the Council Room are sliding doors which enable the two rooms to be made into one when the occasion demands.

Fig. 2 shows a view of the house taken from the terrace at the back, Fig. 3 a view of the Council Room and table and Fig. 4 the Members' Reading Room looking towards the Council Room, and revealing the beautiful arched entrance between the two rooms. Fig. 5 is a close-up view of the top of the Presidential chair, showing the badge embossed in gold on the leather back.

FIG. 6.

*No. 4, Hamilton Place.*
*The Entrance Hall and part of the Main Staircase.*

Fig. 6 shows the entrance hall and main marble staircase. The main staircase, leading to the library and committee rooms, is one of great dignity and beauty, and designed in the spacious Victorian days when Park Lane was a centre for great receptions. Fig. 7 gives a view of the top of the first flight as it reaches the library. There, half-hidden by the pillar in the photograph, may be seen the painting of the Duke of Argyll, the first President of the Society.

For the first time in its long history, the Royal Aeronautical Society has a library worthy of the unique collection of aeronautical books, pamphlets and rare

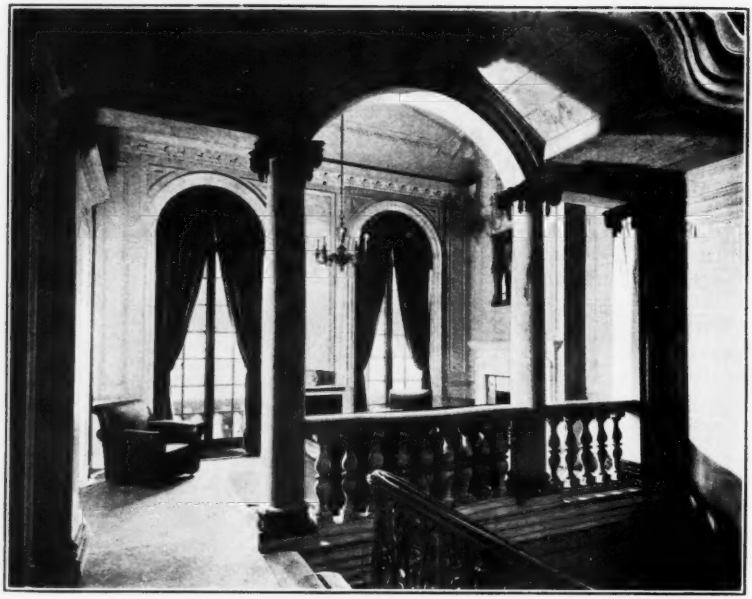


FIG. 7.
*No. 4, Hamilton Place.*
*The Library Landing at the top of the first flight of the Main Staircase.*

FIG. 8.
*No. 4, Hamilton Place.*
*The Library, looking towards Hyde Park.*

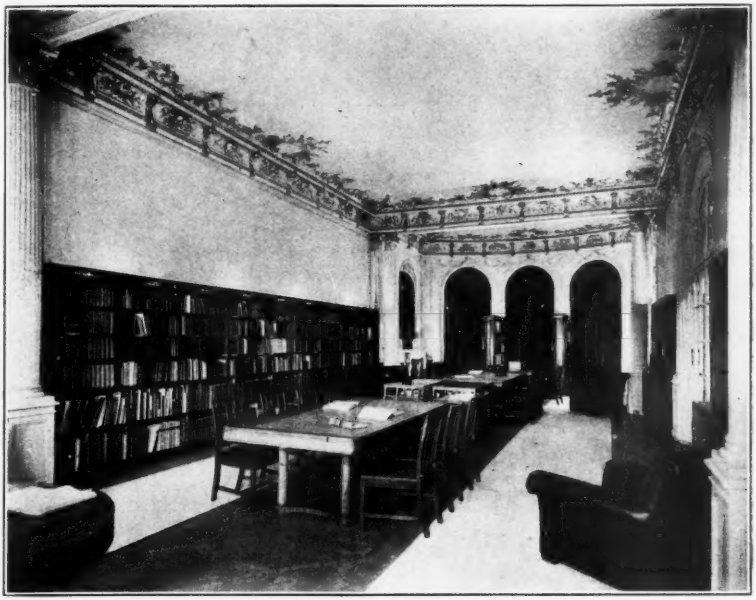


FIG 9.

*No. 4, Hamilton Place.*
*The Library at night, looking towards Hamilton Place.*

FIG. 10.

*No. 4, Hamilton Place.*
*A close-up of the bookshelves at the end of the Library.*

prints which it possesses. The library was originally the ball-room and its beautifully designed proportions make it easily the most dignified library of any of the leading Societies or Institutions.

It is furnished throughout in walnut, with green leather upholstery and green velure curtains. Each end of the library is pillared in marble and fitted with carved marble fireplaces. The ceiling is decorated with heraldic emblems in gold relief, an art which is now almost obsolete. The bookshelves were designed to fit the proportions and dignity of the room itself.

The mirrored doors give the effect of greatly increasing the size of the library. In the centre, Fig. 8, may be seen show cases which enable the Society to show some of its most treasured and unique historical possessions. Fig. 8 gives the view of the library looking through the windows over Hyde Park. These windows,

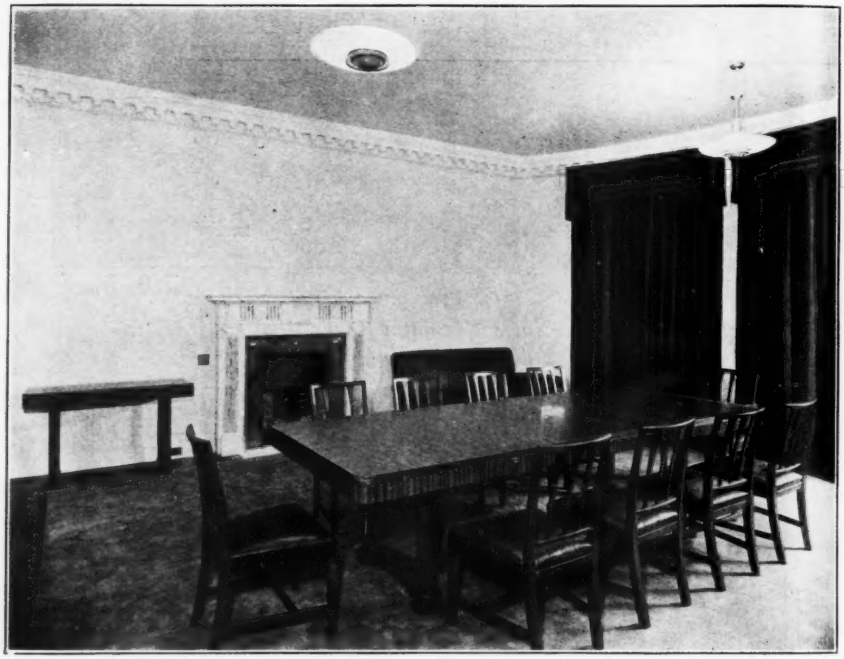


FIG. 11.

*No. 4, Hamilton Place.*
*A view of No. 1 Committee Room.*

like all the windows throughout the house, are double, so that all external sounds may be shut out. Fig. 9 shows the library taken at night, looking towards the Park Lane windows. The whole of the lighting is concealed so that there is no direct glare, anywhere. Fig. 10 gives a close-up view of two of the end bookshelves, showing also one of the small tables where members can work in ideal surroundings.

On the second floor are two special Committee Rooms, where not only Committees of the Council meet, but Committees of other aeronautical and engineering Societies. Fig. 11 shows No. 1 Committee Room furnished in walnut and

upholstered in green, and Fig. 12 part of No. 2 Committee Room furnished in mahogany and upholstered in a deep brown.

The third floor is occupied by the Secretary's office and the general offices, and the fourth floor by the store rooms for the Journal and other publications, the telephone exchange and the accounts department.

No. 4, Hamilton Place belonged to the late Mr. Leopold Albu, who carried out all the original decorations and structural alterations. He spared no expense to make the house one of the most dignified and beautiful in London.

The President and Council hope that every member who has not yet had an opportunity of visiting the new headquarters will make a special point of doing so. They are confident that once a member has seen No. 4, Hamilton Place, he will wish to make frequent use of it.

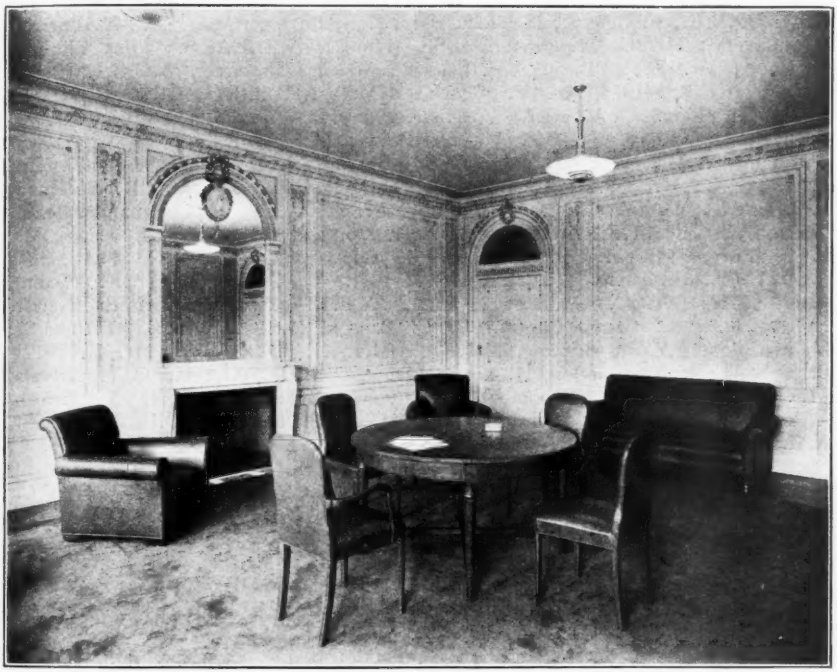


FIG. 12.

*No. 4, Hamilton Place.*
*A view of No. 2 Committee Room and Members' Room.*

So that all members should have the opportunity of seeing No. 4, Hamilton Place, the President and Council invited all members and their ladies to a Reception and Dance. So many early indicated their wish to come that two nights were set aside for the purpose, June 16th and June 17th, 1939. Over 1,100 members and their ladies attended on the two nights and were received by the President, who was assisted by his niece, Miss Betty Fedden, as hostess. Hamilton Gardens were open for the occasion and every opportunity was given for all to see the new home under the best possible conditions.

The following members and guests, accompanied by their ladies, were present at the Receptions and Dances on June 16th and 17th, 1939:—

Mr. C. F. Abell, O.B.E., A.F.R.Ae.S.; Major G. H. Abell, O.B.E., A.F.R.Ae.S.; Colonel A. L. Abbott, F.R.I.B.A.; Captain P. D. Acland; Mr. J. Adam, A.F.R.Ae.S.; Mr. D. R. Adams, A.F.R.Ae.S.; Mr. C. M. Afzel; Mr. J. Aherne-Heron, A.R.Ae.S.I.; Mr. F. D. Aldridge, A.R.Ae.S.I.; Mr. H. R. Ambrose; Mr. L. R. Ambrose, A.R.Ae.S.I.; Mr. D. R. P. Amor, B.Sc., A.F.R.Ae.S.; Mr. B. F. Andersin; Mr. T. B. Andre; Mr. S. T. G. Andrews, B.Sc. (Eng.), M.I.Ae.E.; Mr. L. R. E. Appleton, B.A.; Mr. J. Archdale; Mr. L. S. Armandias; Captain N. Arnaud (Brazilian Naval Attaché); Mr. R. J. Atkinson, B.E.; Mr. F. Austin, A.R.Ae.S.I.

Miss Agnes Baden-Powell; Mr. F. O. Baines; Squadron Leader W. R. Baird, A.R.Ae.S.I.; Professor L. Bairstow, C.B.E., F.R.S., F.R.Ae.S.; Mr. S. Baldwin, A.M.I.Ae.E.; Mr. W. H. Ballantyne, B.Sc., F.C.S.; Mr. F. Rodwell Banks, O.B.E., F.R.Ae.S., M.I.A.E.; Mr. J. F. Barlow; Mr. H. C. N. Barron; Mr. Bartels; Mr. C. M. Barter, B.Sc. (Hons.), A.F.R.Ae.S.; Miss Florence Barwood; Mr. E. L. Bass, A.F.R.Ae.S.; Mr. H. Bateman, A.C.G.I., B.Sc., D.I.C., A.F.R.Ae.S.; Mr. F. Beach, A.M.Inst.Mech.E., A.R.Ae.S.I.; Mr. E. N. B. Bentley, A.C.G.I., A.F.R.Ae.S.; Mr. W. M. Bentley; Mr. F. Bevilacqua, A.R.Ae.S.I.; Mr. W. H. Bewg; Mr. A. E. Bibby; Mr. A. E. Bingham, A.M.I.Mech.E.; Major B. Binyon, O.B.E., M.A., M.I.E.E., A.F.R.Ae.S.; Mr. G. H. M. Birkbeck; Mr. H. Blamberg; Mr. R. Boorman, A.F.R.Ae.S.; Captain F. L. M. Boothby, F.R.Ae.S.; Wing Commander K. L. Boswell, C.B.E., A.F.R.Ae.S.; Mr. R. H. Botterill; Mr. R. T. Bowring; Mr. E. C. Bowyer; Lieut.-Commander A. de Booy (Netherlands Naval Attaché); Mr. H. C. Bradshaw, F.R.I.B.A.; Mr. A. York Bramble, A.A. (Oxon), A.R.Ae.S.I.; Mr. C. G. Brewer, M.A., A.F.R.Ae.S.; Mr. Griffith Brewer, Hon. F.R.Ae.S.; Group Captain E. F. Briggs, D.S.O., O.B.E., F.R.Ae.S.; Lieut.-Colonel W. A. Bristow, M.I.E.E., M.I.A.E., F.R.Ae.S.; Mr. H. W. J. Brittlebank; Air Commodore H. Le M. Brock, C.B., D.S.O.; Mr. C. H. Brooks, A.F.R.Ae.S.; Captain Broome; Mr. F. G. Brown; Mr. H. A. Brown, A.R.Ae.S.I.; Mr. J. D. Brunton; Major J. S. Buchanan, C.B.E., F.R.Ae.S., A.M.I.Mech.E.; Mr. J. B. Bucher, A.F.R.Ae.S.; Mr. B. Buck; Major F. C. Buck, A.F.R.Ae.S.; Mr. F. E. Buckell A.R.Ae.S.I.; Major G. P. Bulman, O.B.E., B.Sc., F.R.Ae.S.; Flight Lieut. P. W. S. Bulman, M.C., A.F.C., R.A.F.O., F.R.Ae.S.; Major F. A. Bumpus, B.Sc., A.R.C.S., Wh.Sch., F.R.Ae.S.; Mr. L. P. Burch, A.R.Ae.S.I.; Mr. D. W. Burland; Mr. R. W. Burn-Callander; Mr. H. Burroughes, F.R.Ae.S.; Mr. F. S. Burt, B.Sc., A.C.G.I.; Mr. G. D. Burton; Mr. T. G. H. Burton; Miss Frances Buss; Mr. A. S. Butler, A.R.Ae.S.I.; Mr. L. F. G. Butler; Mr. J. F. Byrne.

Captain W. H. Cadman; Mr. S. C. Caliendi; Mr. D. Cameron, A.F.R.Ae.S.; Mr. S. Camm, F.R.Ae.S.; Mr. J. D. Campbell, B.Sc., A.R.T.C., A.F.R.Ae.S.; Mr. R. S. Capon, O.B.E., B.A., F.R.Ae.S.; Mr. G. F. Carrington; Mr. R. Chadwick, F.R.Ae.S.; Mr. R. A. Chalmers, O.B.E., A.F.C.; Mr. A. E. Chambers; Air Commodore J. A. Chamier, C.B., C.M.G., D.S.O., O.B.E., A.F.R.Ae.S.; Captain L. W. Charley, O.B.E.; Dr. H. Chatley, A.F.R.Ae.S.; Brigade Commander I. Cherny (Air Attaché to the Soviet Union); Mr. H. Chinery; Miss L. Chitty, F.R.Ae.S.; Mr. A. E. L. Chorlton, C.B.E., M.Inst.C.E., M.I.Mech.E., F.R.Ae.S., M.P.; Lieut.-Colonel B. G. Chyworeth (Military Attaché and Military Attaché for Air to the American Embassy); Mr. A. G. Clark; Mr. W. G. B. Clark; Mr. H. W. Clarke; Mr. G. C. Clarkson; Mr. A. C. Clinton, A.F.R.Ae.S.; Mr. A. A. E. Clutten, A.R.Ae.S.I.; Sir Alan J. Cobham, K.B.E., A.F.C., Hon. F.R.Ae.S.; Squadron Leader S. N. Cole, A.F.R.Ae.S.; Mr. C. B. Collins, O.B.E.; Squadron Leader H. B. Collins, M.A., A.F.R.Ae.S.; Mr. J. V. Connolly, A.F.R.Ae.S.; Mr. E. H. W. Cooke; Mr. G. H. Corbett;

Mr. R. W. Corbitt, M.Sc., D.I.C., A.M.I.Mech.E., A.F.R.Ae.S.; Major J. B. L. Cordes; Mr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc., F.R.Ae.S.; Mr. G. H. Coxon; Mr. H. S. Crabtree, B.A., A.F.R.Ae.S.; Mr. H. J. Crampton, A.F.R.Ae.S.; Mr. F. F. Crocombe, A.C.G.I., D.I.C., B.Sc., A.F.R.Ae.S.; Mr. D. C. Crombie; Mr. J. Crowe, A.F.R.Ae.S., A.F.I.Ae.S.; Squadron Leader W. N. Cumming, F.R.Met.Soc., A.F.R.Ae.S.; Sir Hugo Cunliffe-Owen, Bt.

Dr. C. G. Darwin; Mr. E. R. Davidson; Mr. E. T. J. Davies; Mr. H. Davies, M.Sc., A.F.R.Ae.S.; Mr. M. J. B. Davy, F.R.Ae.S.; Mr. A. L. B. Dawson, A.M.Inst.C.E., A.M.Inst.Mech.E., A.M.I.Ae.E.; Mr. C. Dennis; Miss Sheila Dennis; Mr. L. F. A. d'Erlanger; Mr. W. C. Devereux, F.R.Ae.S., M.I.Ae.E.; Mr. M. Diamant; Mr. D. R. H. Dickinson; Lieut.-Colonel H. A. P. Disney; Mr. F. H. Dixon, A.R.Ae.S.I.; Mr. G. Dobson; Mr. J. Doorly, C.S.B.; Mr. F. O. Dorer, A.R.Ae.S.I.; Mr. D. Douet, A.M.I.Ae.E., F.R.A.; Dr. G. P. Douglas, O.B.E., M.C., F.R.Ae.S.; Air Vice-Marshal W. S. Douglas, M.C., D.F.C.; Mrs. Dumas; Captain G. St. Dumitrescu (Roumanian Military and Naval Attaché); Sir Andrew Duncan; Professor W. J. Duncan, D.Sc., F.R.Ae.S.

Mr. E. J. Earnshaw; Mr. S. G. Ebel, M.Inst.E., A.F.R.Ae.S.; Mr. D. P. Edkins; Lieut.-Colonel I. Edwards, C.M.G.; Mr. D. L. Ellis, B.Sc., A.R.T.C., A.F.R.Ae.S.; Mr. D. J. M. Emerson; Mr. J. B. Emmott; Mr. W. Emmott; Mr. E. C. Gordon England, F.R.Ae.S.; Miss B. Etty-Leal; Mr. W. M. Evans; Air Vice-Marshal D. C. S. Evill, D.S.C., A.F.C.

Mr. A. Fage, A.R.C.Sc., F.R.Ae.S.; Mr. V. M. Falkner, A.F.R.Ae.S.; Mr. W. S. Farren, M.B.E., M.A., F.R.Ae.S., M.I.Ae.E.; Mr. R. W. F. Farthing; Mr. E. J. Fearn, M.Sc. (Eng.), A.M.I.Mech.E., A.F.R.Ae.S.; Mr. A. H. R. Fedden, M.B.E., D.Sc., M.I.A.E., M.I.Mech.E., M.S.A.E., F.R.Ae.S.; Mrs. Vincent Fedden; Miss Betty Fedden; Miss Mary Fedden; Mr. P. Fedden; Mr. Fedden, Junr.; Mr. J. A. Finch, A.M.I.Ae.E.; Mr. M. Firth; Mr. E. G. Fischeles, A.F.R.Ae.S.; Mr. A. A. Fletcher, A.R.C.S., B.Sc., D.I.C., A.F.R.Ae.S.; Mr. R. H. D. Forbes, B.Sc.; Captain A. G. Forsyth; Mr. H. E. Fozard, A.F.R.Ae.S.; Mr. F. J. French; Mr. H. A. Francis, A.F.C., M.A., A.F.R.Ae.S.; Mr. A. Franks; Squadron Leader H. P. Fraser, A.F.R.Ae.S.; Mr. R. A. Frazer, B.A., B.Sc., F.R.Ae.S.; Air Marshal Sir Wilfrid Freeman, K.C.B., D.S.O., M.C.; Mr. D. C. Friend; Mr. A. G. Frost; Mr. B. C. Frost, A.R.Ae.S.I.

Lieut.-Commander B. W. Galpin, R.N.; Mr. G. C. I. Gardiner; Sir Charles Bruce Gardner; Mr. Lester D. Gardner, Hon. F.R.Ae.S.; Mr. W. J. Gessey; Mr. J. F. Gibbon; Mr. F. Gill, A.F.R.Ae.S.; Air Commodore N. J. Gill, R.A.F., C.B., C.B.E., M.C., A.F.R.Ae.S.; Mr. H. R. Gillman, A.F.R.Ae.S.; Mr. K. B. Gillmore, A.F.R.Ae.S.; Major Subhi Goher (Turkish Air Attaché); Mr. J. C. Goldie, A.R.Ae.S.I.; Mr. J. P. Golding; Lord Gorrell, C.B.E., M.C., M.A.; Mr. A. Gouge, B.Sc., F.R.Ae.S.; Mr. A. J. Grant; Mr. W. A. K. Grant; Mr. F. B. Greatrex, B.A.; Mr. C. G. Grey; Mr. W. H. Grieve; Mr. T. D. Griffin; Mr. P. T. Griffith, A.F.R.Ae.S.; Mr. H. Grinstead, O.B.E., B.Sc., A.C.G.I., F.R.Ae.S.; Commander H. Grondahl (Finnish Air Attaché); Brig. Gen. P. R. C. Groves, C.B., C.M.G., D.S.O., A.F.R.Ae.S.; Mr. D. S. Gunning; Mr. R. E. Gustine, A.F.R.Ae.S.

Mr. R. Hafner; Mr. G. H. Hales, A.F.R.Ae.S.; Major F. B. Halford, F.R.Ae.S., M.S.A.E.; Mr. Ashley Hall; Mr. A. H. Hall, C.B., C.B.E., M.Inst.C.E., M.I.Mech.E., F.R.Ae.S.; Mr. G. W. Hall, A.F.R.Ae.S.; Mr. I. M. Hamer; Wing Commander H. A. Hamersley, A.F.R.Ae.S.; Mr. A. A. Hammond, A.F.R.Ae.S.; Mr. M. Hancock, A.R.C.S., B.Sc., A.F.R.Ae.S.; Mr. Maldon Harley, A.R.Ae.S.I.; Dr. W. H. Hatfield, F.Inst.P., M.I.Mech.E., M.I.A.E., A.F.R.Ae.S.; Mr. R. Lee Hayes; Mr. R. M. Hayes; Major H.

Hemming, A.F.C., F.R.G.S., F.R.Ae.S.; Mr. R. C. B. Hendy, A.M.I.Ae.E.; Mr. F. C. Hentsch; Mr. N. P. Heron; Mr. H. G. Herrington; Mr. J. M. Heesem, A.F.R.Ae.S.; Mr. Hickman; Professor F. T. Hill, F.R.Ae.S., M.I.Ae.E.; Professor G. T. R. Hill, M.C., M.Sc., M.I.Mech.E., F.R.Ae.S.; Air Vice-Marshal R. M. Hill, M.C., A.F.C., M.A., F.R.Ae.S.; Miss Hill; Mr. W. F. Hilton, Ph.D., A.R.C.Sc., D.I.C., B.Sc., A.F.R.Ae.S.; Miss D. M. Hirst, M.A., A.F.R.Ae.S.; Mr. F. A. N. Hitch, B.Sc. (Hons.); Commander F. G. Hitch, R.N.; Lieut.-Commander Hitchcock (American Assistant Naval Attaché for Air); Mr. E. W. Hives, F.R.Ae.S.; Mr. A. J. Hobbs; Mr. A. D. Hodgson, A.M.I.E.E., A.F.R.Ae.S.; Mr. J. E. Hodgson, Hon. F.R.Ae.S.; Flight Lieut. C. Hole, A.R.Ae.S.I.; Mr. E. Holgate; Mr. J. V. Holman, A.R.Ae.S.I.; Mr. J. G. Hopcraft, M.C., A.M.I.Ae.E.; Mr. H. O. Houchen, A.F.R.Ae.S.; Mr. J. J. Browne Houston; Mr. H. B. Howard, B.A., B.Sc., F.R.Ae.S.; Mr. L. A. G. Howard, B.A., A.F.R.Ae.S.; Mr. H. S. Howat, B.Sc., A.F.R.Ae.S.; Mr. A. J. Hughes, O.B.E., A.F.R.Ae.S.; Mr. A. Hukins; Mr. S. G. Hulbert; P./O. A. K. Hunter, B.Sc.; Mr. F. A. Hurst; Mr. K. A. Hurst, A.R.Ae.S.I.; Mr. G. A. P. Hunt.

Wing Commander L. M. Iles, D.I.C., A.F.R.Ae.S.; Lord Illingworth; Lieut.-Colonel T. Imasato (Japanese Assistant Military Attaché for Air); Mr. K. R. Imeson; Mr. H. B. Irving, B.Sc., F.R.Ae.S; Mr. W. Isbister, B.Sc., B.E.

Mr. A. N. Jackson, B.Sc. (Eng.), A.F.R.Ae.S.; Mr. C. H. Jackson, B.Sc., A.C.G.I., D.I.C., A.F.R.Ae.S.; Dr. J. Jakobi; Dr. L. Jakobi; Mr. T. G. John, F.R.Ae.S., M.Inst.C.E., M.I.N.A., M.I.A.E.; Mr. L. W. Johnson, M.C., M.Met., A.F.R.Ae.S.; Miss Brenda Jones; Mr. B. R. S. Jones; Mr. H. E. Jones; Mr. J. L. B. Jones, B.Sc. (Hons., Eng.), A.F.R.Ae.S.; Mr. R. Glyn Jones; Professor B. Mevill Jones, C.B.E., A.F.C., M.A., F.R.Ae.S.; Mr. V. G. Jones, A.F.R.Ae.S.; Mr. O. T. Jones; Mr. J. Julien.

Mr. G. L. Keen, A.F.R.Ae.S.; Mr. A. S. Keep, M.C., B.Sc., A.F.R.Ae.S.; Captain E. Keith-Davies, A.F.R.Ae.S.; Mr. M. J. I. Kemper; Major D. H. Kennedy, O.B.E., F.R.Ae.S.; the Rt. Hon. Lord Kenilworth, C.B.E., F.R.Ae.S.; Miss Jean Kerr; Monsieur I. Smith Kielland (Norwegian Counsellor); Mr. E. P. King, B.Sc., A.F.R.Ae.S.; Mr. P. G. G. Knight; Flight Lieut. R. J. Knights-Whittome, A.R.Ae.S.I.; Mr. H. Knowler, A.M.Inst.C.E., F.R.Ae.S.; Lieut.-Colonel B. J. Kwiecinski (Polish Air Attaché).

Mr. J. E. Lamb, A.M.I.Ae.E.; Captain A. G. Lamplugh, F.R.Ae.S., M.I.Ae.E.; Mr. M. Langley, M.I.Ae.E., A.M.I.N.A.; Mr. J. H. B. Larrard, A.F.R.Ae.S.; Mr. C. W. Lawson; Mr. J. W. Layfield; Mr. W. L. Lax, A.M.I.Ae.E.; P./O. H. Ledger, A.M.I.Ae.E.; Mr. G. H. Lee, B.Sc., A.R.C.S., D.I.C., A.F.R.Ae.S.; Mr. J. H. Lees, A.F.R.Ae.S.; Mr. M. Lewin, A.F.R.Ae.S.; Professor F. A. Lindemann, Ph.D., F.R.S., F.R.Ae.S.; Mr. F. H. M. Lloyd; Mr. R. M. Lloyd, A.R.Ae.S.I.; Mr. C. N. H. Lock, M.A., F.R.Ae.S.; Mr. E. R. Locke, A.M.I.Ae.E.; Mr. J. W. C. Logan, A.M.I.Ae.E.; Mr. P. C. Lombardini, A.F.R.Ae.S.; Mr. C. D. Long, A.M.I.Ae.E.; Mr. E. Lord; Mr. G. N. F. Luckie; Group Captain D. Lucking, A.F.R.Ae.S.; Mr. G. Lyon; Mr. H. R. H. Lyster, A.R.Ae.S.I.

Major G. McAlpine, M.I.E.E., A.F.R.Ae.S.; Mr. A. L. McColl; Mr. H. E. McCormick; Major McCrindle; Major G. C. McDonald (American Assistant Military Attaché for Air); Mr. M. McElligott; Mr. D. McKellar; Mr. F. McKenna, M.I.Ae.E.; Miss Beth Macava; Mr. J. W. Maccoll, B.Sc., Ph.D., A.F.R.Ae.S.; Mr. R. G. MacLeod; Captain N. Macmillam, M.C., A.F.C., A.F.R.Ae.S., F.R.S.A.; Mr. G. M. M. Magill; Mr. H. M. D. Magill; Mr. F. I. Marking; Lieut.-Colonel W. Lockwood Marsh, O.B.E., M.A., Ll.B., M.S.A.E., A.F.I.Ae.S., F.R.Ae.S.; Mr. A. H. Martin, A.F.R.Ae.S.; Mr. P. G. Masefield,

B.A., A.F.R.Ae.S.; Mr. R. Borlase Matthews, F.R.Ae.S., A.M.Inst.C.E.; Mr. F. Mayer; Major R. H. Mayo, O.B.E., M.A., A.M.Inst.C.E., F.R.Ae.S.; Mr. F. T. Meacock; Mr. G. A. R. Mead; Mr. D. O. Meredith, B.A., B.A.I., A.M.Inst.C.E.I., A.M.I.Ae.E.; Mr. F. W. Meredith, B.A., A.F.R.Ae.S.; Mr. H. A. Mettam, M.A., F.R.Ae.S.; Mr. J. H. Millar, A.R.Ae.S.I.; Mr. R. W. Molyneux; Lieut.-Colonel J. T. C. Moore-Brabazon, M.C., F.R.Ae.S., M.I.Ae.E., M.P.; Mr. H. H. Morris; Mr. R. D. Morrison, A.R.Ae.S.I.; Mr. G. Mortimer; Mr. P. F. Mouritz; Mr. N. S. Muir, A.M.I.Mech.E.; Mr. F. A. L. Muntz, B.A., A.M.I.A.E.; Mr. W. D. Murray, A.F.R.Ae.S.; Lady Muskerry; Mr. A. C. Myers, A.R.Ae.S.I.; Major H. Myers, F.R.Ae.S., M.I.E.I.

Mr. S. G. E. Nash, A.F.R.Ae.S.; Mr. J. L. Nayler, M.A., F.R.Ae.S.; Air Chief Marshal Sir Cyril L. N. Newall, G.C.B., C.M.G., C.B.E., A.M.; Mr. D. R. Newman; Mr. R. L. Ninnes, A.F.R.Ae.S.; Mr. F. Nixon, B.Sc. (Eng.), A.F.R.Ae.S.; Mr. G. W. Nunn, A.R.Ae.S.I.

Miss Winifred Oliver; Mr. H. Campbel Orde; Mr. A. Osborne, A.R.Ae.S.I.; Mr. G. E. Otter; Mr. W. A. Oubridge; Mr. J. B. B. Owen, B.Sc., A.F.R.Ae.S.; Mr. E. Ower, B.Sc., A.C.G.I., F.R.Ae.S.; Mr. F. M. Owner, M.Sc., F.R.Ae.S.

Mr. F. Handley Page, C.B.E., F.R.Ae.S., M.I.Ae.E.; Mr. J. Lankester Parker, A.F.R.Ae.S.; Mr. J. J. Parkes; Miss Rosalind Parkes; Mr. D. S. Paul; Mr. J. H. Payne, B.Sc., A.C.G.I., D.I.C., A.F.R.Ae.S.; Mr. L. Pekarsky; Captain E. W. Percival, M.I.Ae.E.; Mr. G. T. Perkins, A.R.Ae.S.I.; Mr. H. E. Perrin; Mr. S. C. Perry; Dr. N. A. V. Piercy, M.I.Mech.E., A.M.Inst.C.E., F.R.Ae.S.; Mr. R. K. Pierson M.B.E., B.Sc., A.M.Inst.C.E., F.R.Ae.S.; Professor A. J. Sutton Pippard, M.B.E., D.Sc., M.I.C.E., F.R.Ae.S.; Mr. St. John Pleviss; Captain A. O. Pollard, V.C., M.C., D.C.M.; Mr. P. A. H. Pooley; Squadron Leader C. H. Potts, A.F.R.Ae.S.; Mr. C. M. Poulsen; Dr. F. W. Poynton; Major H. Waymouth Prance, A.F.R.Ae.S.; Mr. K. Preston; Flight Lieut. R. C. Preston, A.F.C., A.M.I.Ae.E.; Captain J. Laurence Pritchard, Hon. F.R.Ae.S., A.F.I.Ae.S.; Mr. P. Pritchard; Senor A. Puig-Arosemena (Ecuadorian Acting Charge d'Affaires); Mr. R. Purves, A.F.R.Ae.S., A.M.I.M.E.; Mr. D. R. Pye, C.B., F.R.S., M.A., Sc.D., F.R.Ae.S., M.I.Mech.E.

Miss G. M. B. Quennell, A.F.R.Ae.S.

Mr. H. G. Radlett; Mr. J. H. Randall; Monsieur Gustav Rasmussen (Denmark Legation); Dr. Villibald Rand (Estonian Counsellor); Squadron Leader C. A. Rea, A.F.R.Ae.S., A.M.I.Mech.E.; Mr. E. W. Reissner, B.Sc., D.I.C.; Mr. J. D. K. Restler, M.Inst.C.E., M.I.Mech.E., M.I.E.E., F.R.Ae.S.; Mr. L. G. S. Reynolds, C.B.E.; Mr. R. Rhodes, M.I.Ae.E.; Mr. G. Wigham Richardson; Mr. H. Richardson; Mr. M. C. Rigby, B.A., A.F.R.Ae.S.; Mr. R. A. Robbins, A.F.R.Ae.S., A.M.I.Mech.E.; Mr. F. A. Roberts, A.F.R.Ae.S.; Mr. H. Roberts; Mr. J. M. L. Roberts; Mr. J. V. Roberts, A.R.Ae.S.I.; Miss Anne Robinson; Mr. H. Robinson; Mr. P. P. Robinson; Mr. W. E. Rootes; Mr. G. F. W. Roper; Mr. T. W. D. Ross; Wing Commander H. V. Rowley, A.F.R.Ae.S.; Mr. A. E. Russell, B.Sc., F.R.Ae.S.

Mr. F. E. N. St. Barbe; Miss Peggy Salaman; Captain Sanders; Lieut.-Commander Kinnersley Saul; Mr. W. P. Savage, A.M.I.Aut.E., F.R.Ae.S.; Colonel M. F. Scanlon (late Assistant Military Attaché to the American Embassy); Mr. R. H. Schlotel, A.F.R.Ae.S.; Mr. R. J. Schmidt, Ph.D., A.F.R.Ae.S.; Fliegeroberstabsingenieru Schwencke (German Assistant Air Attaché); Mr. J. W. Scott; Mr. S. Scott-Hall, M.Sc., D.I.C., A.F.R.Ae.S.; Wing Commander A. F. Scroggs, B.A., D.I.C., A.F.R.Ae.S.; Mr. G. R. Scruby; Major T. P. Searight, A.F.R.Ae.S.; Mr. A. H. Self, C.B.; Lord Sempill, A.F.C., F.R.Ae.S.; Lieut.-

Colonel Sir Francis Shelmerdine, O.B.E., C.I.E., F.R.Ae.S.; Major B. W. Shilson, O.B.E., M.I.Mech.E., F.R.Ae.S.; Squadron Leader E. Shipley, M.A. (Cantab), A.F.R.Ae.S., R.A.F.; Mr. A. J. Sidery, A.F.R.Ae.S.; Mr. F. Sigrist, M.B.E., F.R.Ae.S.; Mrs. Walker Sinclair; Miss Simms; Mr. F. R. Simms, M.I.Mech.E., M.I.A.E., M.I.Ae.E., F.R.Ae.S.; Major E. M. Sinauer, M.C., A.M.I.Ae.E.; Group Captain J C. Slessor, D.S.O., M.C., A.D.C.; Mr. H. G. Small; Mr. A. G Smith; Mr. A. N. D. Smith, F.C.A.; Mr. M. A. Smith; Captain P. W. Smith, O.B.E., M.I.Aut.E., A.F.R.Ae.S.; Mr. S. O. Smith, A.F.R.Ae.S.; Mr. T. S. Smith, B.Sc., A.M.I.Mech.E., A.F.R.Ae.S.; Group Captain J. Sowrey, D.S.O., A.F.C., M.C., M.I.Ae.E.; Mr. H. P. Speake, A.F.R.Ae.S.; Lieut. F. J. Spearman, A.M.I.Mech.E.; Mr. K. J. Spooner; Mr. H. N. Sporborg; Mr. G. I. Sprent; Mr. Squire; Mr. R. S. Stafford, A.F.R.Ae.S.; Mr. R. Stamers; Flight Lieut. C. S. Staniland, A.R.Ae.S.I.; Mr. G. Steel; Mr. L. C. Steinle; Mr. A. V. Stephens, F.R.Ae.S.; Mr. W. H. Stephens; Major C. J. Stewart, O.B.E., F.R.Ae.S.; Mr. D. C. Stewart; Mr. H. J. Stieger, D.I.C., A.F.R.Ae.S.; Mr. J. R. Standring; Captain R. H. Stocken, M.I.Ae.E.; Mr. Whitney Straight; Sir Arthur Street, K.B.E., C.B., C.M.G., C.I.E., M.C.; Mr. W. A. J. Street, A.R.Ae.S.I.; Mr. J. G. Strong, B.Sc., A.C.G.I., A.F.R.Ae.S.; Mr. E. A. Stroud, B.Sc.; Mr. A. Swan, B.Sc., A.M.Inst.C.E., A.F.R.Ae.S.; Dr. T. Swinden, F.R.Ae.S.; Mr. J. Summers.

Mr. H. D. Tabakman; Lieut.-Commander A. P. Targett-Adams; Mr. A. G. A. Tawell, B.Sc., Grad.I.E.E., A.F.R.Ae.S.; Mr. C. W. Taylor; Mr. H. B. Taylor, A.F.R.Ae.S.; Air Vice-Marshal Tedder, C.B.; Mr. R. A. Thom, O.B.E., M.I.Mech.E.; Mr. F. A. Thomas, A.M.I.Mech.E.; Mr. F. M. Thomas, F.R.Ae.S.; Mr. H. J. Thomas, F.R.Ae.S.; Mr. A. E. Thornton; F./O. F. O. Thornton, A.F.R.Ae.S.; Mr. T. Thornycroft; Dr. A. P. Thurston, M.B.E., M.I.Mech.E., M.I.A.E., M.I.Ae.E., F.R.Ae.S.; Monsieur L. Tillitse (Danish Counsellor); Mr. A. H. Tiltman, B.Sc., F.R.Ae.S.; Mr. J. D. Titler; Dr. H. C. H. Townend, F.R.Ae.S.; Mr. B. W. Townshend, A.C.G.I., A.M.I.Mech.E., F.R.Ae.S.; Mr. A. M. Tucker; Major C. C. Turner, A.F.R.Ae.S.; Group Captain C. Turner, A.F.C., B.A., A.F.R.Ae.S.; Mr. L. G. A. Turner; Mr. T. H. Turner, M.Sc., A.R.Ae.S.I.; Mr. W. L. Tweedie, A.F.R.Ae.S.

Lieut.-Colonel R. de Utassy (Hungarian Military Attaché); Mr. C. F. Uwins, A.F.C., A.F.R.Ae.S.

Sir Robert Vansittart; Sir Louis Vaughan, K.C.B., K.B.E., D.S.O.; Miss A. Verdon-Roe; Miss V. Verdon-Roe; Sir Alliott Verdon-Roe, Kt., O.B.E., F.R.Ae.S., M.I.Ae.E.; Mr. G. Verdon-Roe; Baron Vincotte (Belgian Military Air Attaché); Mr. M. H. Volk, F.R.Ae S.; Mr. G. R. Volkert, F.R.Ae.S.; Miss Betty Voyce.

Mr. M. M. Waghorn, the Rt. Hon. Viscount Wakefield of Hythe, C.B.E., Hon. F.R.Ae.S.; Mr. C. C. Walker, A.M.Inst.C.E., F.R.Ae.S.; Mr. P. B. Walker, M.A., Ph.D., A.F.R.Ae.S.; Mr. R. W. Walker, A.F.R.Ae.S.; Mr. J. P. Walters; Mr. F. D. Ward; Miss Joan Ward; Captain C. E. Ward, A.R.Ae.S.I.; Mr. A. J. A. Wallace-Barr; Mr. B. N. Wallis, B.Sc. (Eng.), M.Inst.C.E., F.R.Ae.S.; Mr. G. Wansbrough; Dr. H. C. Watts, M.B.E., D.Sc., M.Inst.C.E., F.R.Ae.S.; Dr. Chen Wei-Cheng (Counsellor for China); Air Commodore J. G. Weir, C.M.G., C.B.E., F.R.Ae.S.; Air Vice-Marshal W. L. Welsh, C.B., D.S.C., A.F.C.; Mr. A. P. West, A.F.R.Ae.S.; Mr. T. C. L. Westbrook; Captain W. W. White, A.F.R.Ae.S.; Dr. S. Whyte; Mr. E. Wieser, B.Sc., D.I.C., A.F.R.Ae.S.; Captain A. S. Wilcockson, O.B.E., A.F.R.Ae.S.; Mr. E. W. C. Wilkins, B.Sc. (Hons.), A.F.R.Ae.S.; Mr. D. L. Hollis Williams, B.Sc.; F.R.Ae.S.; Mr. G. H. C. Willins, M.A., A.F.R.Ae.S.; Mr. P. N.

Willoughby, A.F.R.Ae.S.; Mr. F. P. Wills, B.Sc., A.M.I.E.E.; Mr. G. Wilson; Mr. H. E. Wimperis, C.B., C.B.E., M.A., M.I.E.E., F.R.Ae.S.; Mr. L. A. Wingfield, M.C., D.F.C., A.R.Ae.S.I.; Mr. D. B. Winter; Mr. J. A. Withnell; F./O. H. C. Witts, A.M.I.Ae.E.; Mr. H. J. Wolffsohn; Mr. K. J. B. Wolfe, M.Sc., A.I.C., A.F.R.Ae.S.; Mr. L. J. Cardew Wood, A.C.G.I., B.Sc., A.F.R.Ae.S.; Mr. R. McKinnon Wood, O.B.E., A.M.Inst.C.E., F.R.Ae.S.; Lieut.-Colonel L. F. E. Wouters (Belgian Air Attaché); Mr. S. S. Wyllie.

Mr. A. Hampden Yates, B.Sc. (Eng.); Mr. H. M. Yeatman, M.A., A.F.R.Ae.S., A.M.I.Ae.E.; Mr. A. D. Young, B.A. (Cantab); Mr. A. P. Young; Mr. G. B. Young; Mr. R. T. Youngman, B.Sc., F.R.Ae.S.

Mr. R. Zdanowich, M.A. (Eng.).

*The 638th Lecture read before the Royal Aeronautical Society since its foundation on January 12th, 1866.*

## PROCEEDINGS.

At a meeting of the Royal Aeronautical Society, held in the lecture hall of the Institution of Mechanical Engineers, Storey's Gate, Westminster, London, S.W.1, on Thursday, November 17th, 1938, a paper on the work of the D.V.L. (the Deutsche Versuchsanstalt für Luftfahrt, the German Aeronautical Research Institute) was presented by Dr. F. Seewald.

In the chair: Mr. W. S. Farren, M.B.E., M.A. (Fellow).

The CHAIRMAN: He offered a hearty welcome to Dr. Seewald. At the same time, he expressed regret that Mr. D. R. Pye (Director of Scientific Research, Air Ministry) had been prevented by a bad cold from presiding at the meeting.

It was indeed a pleasure, he continued, to have the opportunity of meeting Dr. Seewald, the active Head of one of the greatest and best equipped aeronautical laboratories in the world. Dr. Seewald had been concerned with aviation long before he had become connected with the D.V.L., for during the war he had served as a pilot and thus had gained active experience of aviation, a very valuable asset to anyone who was concerned with research in aeronautics. After the war he had devoted himself for a time to more academic pursuits, under Professor von Karman at Aachen. Some ten years ago he had joined the D.V.L. in charge of the department dealing with aerodynamics, experiments in flight and work on structural problems. Then, four or five years ago, he had turned to more administrative activities, and anyone who had visited the D.V.L. during the last five years and had noted its great expansion, for which he had been largely responsible, would appreciate that he had had his hands full. During the last three years he had served as its Head.

## "THE WORK OF THE D.V.L."*

By Dr. F. SEEWALD.

Before beginning my lecture, I should like to say that it gives me particular pleasure to be able to take part, as a guest, in this meeting of the Royal Aeronautical Society. So much important progress in the development of aeronautics has had its origin within the circle of the Royal Aeronautical Society, the oldest society of its kind in the world, and so many successes in the scientific and practical spheres are coupled with the names of its members that all the staff of the D.V.L. regard as a particular honour the friendly interest in our work, expressed by your invitation.

The D.V.L. the full title of which is Deutsche Versuchsanstalt fur Luftfahrt, *i.e.*, in English The German Aeronautical Research Institute, on whose work I have to report in accordance with your invitation, is the central scientific aeronautical institute in Germany. Besides the D.V.L., there are some other institutes in Germany who also deal with aeronautics. In contrast to the D.V.L. these other institutes, which are usually associated with universities, work for the most part on some special branch, *e.g.*, the well-known Institute of Aerodynamics in Gottingen on the aerodynamic branch, or the Deutsche Forschungsinstitut fur

* Translated by Lionel Mote, A.I.L.

Segelflug, *i.e.*, in English, the German Research Institute for Soaring Flight, in Darmstadt, on the branch dealing with Soaring Flight.

The D.V.L., on the other hand, has the task of extending its activities over all the departments whose application is of importance for technical development in aeronautics, and they are, as you all know very well, almost every branch of physical and engineering science.

Our task consists, then, in facilitating and furthering, as much as possible, by scientific work in all these many separate departments, the practical progress in the various branches of technical development. The ways and means, by which these problems can best be solved, are, on the whole, left to us. In the D.V.L., as in many other technical research institutes, the following methods of working have, in the course of time, been adopted: On the one side we work in close co-operation with the Air Ministry, the Industry or the German Luft Hansa, on certain practical problems. On the other hand, by extensive research on the basic problems of flight, we endeavour to enlarge the stock of scientific knowledge, and in this way, to improve the scientific basis required by the practical engineer.

The first mentioned part of the work comes to us generally in the shape of commissions on behalf of the Air Ministry, the Industry, or sometimes of the German Airways. When, in the construction, or testing of an aeroplane, or of an engine, or in the investigation of accidents, the co-operation of a specialist or the carrying-out of special tests is required, then we are called in to take part in the solution of the problem or in the improvement of the apparatus in question. In these cases our activities are exactly similar to those of a consulting engineer. In such work it is, generally, not a question of gaining new scientific knowledge, it is rather a question of applying the already existing knowledge in order to attain, as quickly as possible, a practical goal with the least possible risk. Commissions of this kind are usually paid for by the people who place them.

The programme for the second part of our work is influenced, in the first place, by the Air Ministry, which provides us with the necessary funds. Then, in scientific work we receive the support of the committee of experts of the Lilienthal-Gesellschaft, where the foremost technical people in the various branches meet regularly in order to discuss the urgency and the possibilities of success of individual problems, the work already in progress, the development aimed at and its practical value. In this way we obtain certain guiding principles and suggestions for that part of our work which is devoted to generally interesting problems, independently of any commission for a scientific elucidation which may be on hand at the moment.

When, some seven years ago, Dr. Hoff, my predecessor as leader of the D.V.L., gave a lecture on the same subject as I, to-day, before your society, he mentioned another department, with which we are no longer concerned. That is the testing of samples and the certification of aircraft. Since the German Air Ministry was formed five years ago it has taken over this work which was formerly conducted by the D.V.L. We still co-operate, in the drawing up of the regulations, as well as in particular cases, in the testing of the aircraft. Here again, our co-operation takes the character of the advisory activity of a consulting engineer.

This alteration was necessary, if only for the reason that the D.V.L. has not the powers of an authority. Since its foundation in 1912, it has been formed, legally, as well as in its internal organisation and management, like a private firm. In former times it was allowed to use powers of authority, as a temporary measure, but this was altered when German aviation was reorganised five years ago.

As already explained in the introduction, the greater part of the work which is carried out in the technical departments, is directed towards practical problems in order to support the industry in its commissions in the design or constructional stages. It is naturally not proper to explain this part of the work here, since it is concerned, not with a complete solution in the scientific sense, but with the attainment of a definite, practical purpose. Moreover, when working as a con-

sulting engineer with, or on behalf of a firm, it is, in most cases, left to the employer, whether he will report on the result or not, or when he will do so. In order to retain the confidence of the various firms, in competition with each other, we have to be very careful on this point. I will mention as examples,* illustrating the work of the D.V.L., only that work not connected with any definite commission, but that which may be treated as of general interest in order to support the continually progressing improvements in military and civil aircraft.

In the choice of the problems to be treated in this manner, the experience gained in practice is a valuable help. This experience is strengthened by suggestions obtained from the Air Ministry and the committee of experts of the Lilienthal-Gesellschaft.

In order to form a clearer judgment of these results and suggestions, we carry out investigations, not in order to attain scientific results, but in order to foresee as soon as possible future development and the problems arising from it. Here, questions of the following kind are dealt with: What will be the speed required and attained, in a few years time, by military and civil aircraft? What will be the altitudes reached for military and civil purposes? What will be the dimensions of civil and military aircraft and the engines for such aircraft? What are the technical problems which must be solved scientifically in order that these aircraft of the future may be successfully designed and built? I believe that a research institute which answers these questions correctly and as soon as possible, will have made an important step toward the successful solution of the problem. With us, it is, above all, the duty of the heads of the three main departments (1) the aeroplane (2) the engine and (3) the equipment department, to form a judgment on these questions by observation of the technical development and by corresponding investigations.

I will now pass on to illustrate by some examples the work concerning aircraft and I will begin, next, with some sections of such work, which are suited to show an analysis of the expected requirements in aeronautics by scientific knowledge.

A very important question is, for example, in what way and by what means can further increases in speed be obtained with tolerable expense. In this connection it is of value to form an opinion on the lowest possible drag, which appears to be generally obtainable. Writers in your country have concerned themselves with this question, *e.g.*, Melvill Jones, " The Streamline Aeroplane," J. Royal Aeronautical Society, Vol. 33. The knowledge of such a limit has, on the one hand, the advantage that the drag of any completed aeroplane can be compared with this minimum drag and thereby is provided a reliable standard for the judgment of the aerodynamic value of an aeroplane. On the other hand, such a comparison of the drag of practical, already-completed aircraft with the extreme, attainable drag, gives a valuable indication whether further important progress can be expected, *i.e.*, whether it is worth while carrying out extensive tests, and from an analysis of the various drag components, it can be decided to which part attention should be directed in order to obtain the greatest possible improvement.

For this purpose, a hypothetical aeroplane can be imagined, having, for every part, the drag which is accepted, in the present-day condition of physical knowledge, as the lower limit. In the cases where the lowest possible drag cannot be calculated theoretically with the necessary reliability the most favourable measured values can be substituted. For the wings, for example, that drag can be substituted which was measured at corresponding Reynolds numbers on the most favourable aerofoil sections of corresponding thickness ratio and with carefully polished surfaces, and, for the fuselage, that obtained by measurement on bodies of revolution of the best airship shape and of equal volume. In this case we choose the measurements of the bodies so that they are of the same length and volume as

* All work reported here will appear in the 1938 Year Book of the D.V.L., so long as it has not already appeared in the 1937 Year Book.

the fuselage of the aeroplane under consideration. For the radiators, we assume that drag which appears to be attainable with the best shape, and which can be measured on correspondingly shaped radiators by themselves, and we proceed, in the same manner with the drag of the tail-unit. If now we imagine all these parts of an aeroplane put together and all the separate parts of the drag are added together in the assumption that no increase, by interference, in the total drag takes place, then we obtain the drag of the hypothetical aeroplane, which we denote as the lowest possible drag for an aeroplane of these dimensions.

If then the drag measured on existing aeroplanes is compared with the " minimum drag," obtained for a hypothetical aeroplane in the above manner, then it is seen that the best modern aircraft have a drag value approximately twice as large as this " minimum drag." In order to determine the best approximation that may be obtained to this " minimum drag," not only with hypothetical but also with aeroplanes constructed in practice, the same comparison was carried out with two models, which were constructed with special care in all details, and measured in the wind tunnel of the D.V.L. The result was that the drag obtained was 1.3 times the " minimum drag " as against the two-fold drag of existing aircraft. It appears then that the hope is justified that the drag of modern fast aircraft can be reduced in the ratio of 2:1.3, that is, by some 30 per cent. This would mean an increase in speed of some 10 per cent., which could be obtained without increasing the engine performance or the landing speed and without entailing any other disadvantages, merely by the more careful development of the external shape.

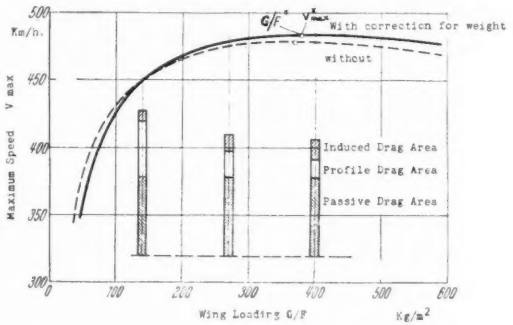



FIG. 1.

*Maximum speed of a high speed aircraft for various wing loadings at 4 kms. altitude (equal aspect ratio* $\Lambda = 8$).
Power weight ratio $\eta N/G = 0.2$ h.p./k.g.
Passive drag ratio $fus'/G = 0.1 \cdot 10^{-3}$ m.²/kg.
Ordinate—maximum speed.
Abscissa—wing loading.

It was shown in the analysis of the separate drag components, that the drag of the radiators and engine nacelles is farthest removed from the lower limit which can be held as attainable. These parts merit, therefore, the particular attention of the expert in aerodynamics. At the same time, it can be seen from these considerations (apart from the influence of the compressibility of the air) that an increase in the speed of aeroplanes, by aerodynamic improvements, is limited and that in the course of the last ten years a large section of the possible aerodynamic improvement has already been carried out. So long as no basically new discovery in physical knowledge is made, which involves new possibilities, we must content ourselves with the steps in progress indicated above.

Such a new discovery would be made, if, for example, it became possible so to influence the airflow over the wings and fuselage that the boundary layer did not become turbulent, at a short distance—in comparison with the dimensions of the aeroplane—from the leading edge, but remained laminar over the largest possible section, by which means the drag would be very considerably reduced. If something of this kind were discovered, then an important step forward in aeronautics would be possible.

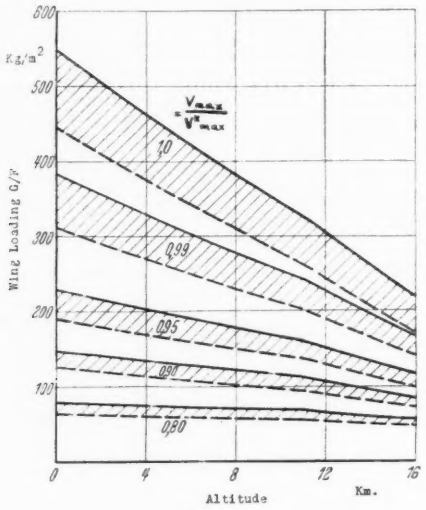



FIG. 2.

*The influence of altitude on the choice of wing loading.*

Power weight ratio $\eta N/G' = 0.2$ h.p./kg.
Passive drag ratio $fws'/G' = 0.05 \cdot 10^{-3}$ m.²/kg. ($C_{wp}$ 0.006).
$= 0.1 \cdot 10^{-3}$ m.²/kg. ($C_{wp}$ 0.01).
Aspect ratio $\Lambda = 8$.
Maximum speed with most favourable wing loading = $v^x$ max.

In the past decade, in order to attain higher speeds, much use has been made of a method, which is really not an aerodynamic improvement, but merely a higher valuation of speed as against the other characteristics. This method, of reducing drag, consists in reducing the area of the active surfaces, so that the wing loading is increased. The question can then be asked:—Is there any sense in increasing the wing loading further, or is the gain in speed obtained at too great an expense, in view of the increase in the landing speed, the vertical speed of descent and the consequent increasing difficulties in take-off and landing? I should like to illustrate briefly the result of an investigation on this subject. Fig. 1 shows how, at an altitude of 4 kms., the maximum speed of an aeroplane, of which the power loading is 0.2 h.p. per kg.—this corresponds to a fast civil aircraft—alters with a variation of the wing loading, by alteration of the wing area. The aspect ratio is assumed to be the same ($\lambda = 8$) for the aerofoils of different dimensions. It will be seen from the diagram, that in the region of the lower wing loadings, every increase in the loading entails an increase in speed. Even between 100 and 200 kg./m.², the speed increases to some extent, but in the region of 200 kg./m.² the maximum is already approached, and it may be hardly worth while (in the case of aeroplanes with the presupposed

characteristics) to go very much in excess of 150 kg./m.², in view of the difficulties in take-off and landing.

If the same calculation is carried out at different altitudes but with the same characteristics of the aeroplane (equal power loading 0.2 h.p./kg. and aspect ratio $\lambda=8$), and if the altitude is plotted against the wing loading, for which the maximum speed is obtained at that height, then the result is the topmost curve in Fig. 2. The use of a shaded strip instead of a line is explained by the fact that the same calculation was carried out, once, with the assumption of extremely favourable values. If the construction of a corresponding aircraft were carried out, the result would lie within the shaded strip. It is of interest now, to know how far the wing loading may be reduced if 1 per cent. or 5 per cent. of the optimum speed is sacrificed. It can be seen that the wing loading, which gives the maximum attainable speed at a constant altitude, falls away sharply with increasing height. The maximum speed at sea level is reached with approximately 500 kg./m.², at 4 kms. with 350 kg./m.² and at 10 kms. with 300 kg./m.²; 95 per cent. of this maximum speed can, however, be attained at sea level, with 200 kg./m.², at 4 kms. with 180 kg./m.² and at 10 kms. with 150 kg./m.².

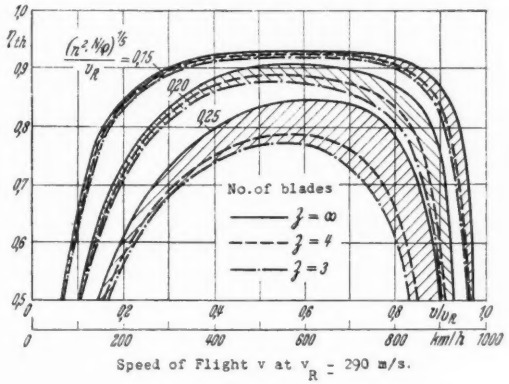



FIG. 3.

*Theoretical efficiency in relation to the speed of flight* ($z=\infty$, 4, 3).

$\eta_{th}$ theoretical efficiency ($\varepsilon_p=0.03$).
$v_R=\sqrt{u^2+v^2}$ = tip speed.
$N$ output of motor.
$n$ revs. airscrew.
$\rho$ density of air.

Other calculations of a similar nature can be made for other types of aircraft, especially for other values of the power/weight ratio. All the values calculated in this manner can be compared with, and corrected from, the results of existing aircraft. By this means, a very reliable basis is obtained for forming an opinion, in connection with corresponding research on engines, fuel consumption, etc., as to the direction in which progress seems most probable and as to whether the prospective increases in weight and drag are worth while.

The results of an extensive investigation of this nature, concerning the possibilities of airscrew thrust, are given in Fig. 3. For three different values of the term $(n^2N/\rho)^{1/5}/v_R$ the attainable efficiency is represented in relation to the ratio $v/v_R$ ($v/v_R$ is the ratio of the speed of flight to the resultant airscrew tip speed, $n$ the number of revolutions, $N$ the engine power and $\rho$ the density of the air). The value of the expression $(n^2N/\rho)^{1/5}/v_R$ at normal revolutions, diameters and performance, lies generally between 0.18 and 0.22. The three middle

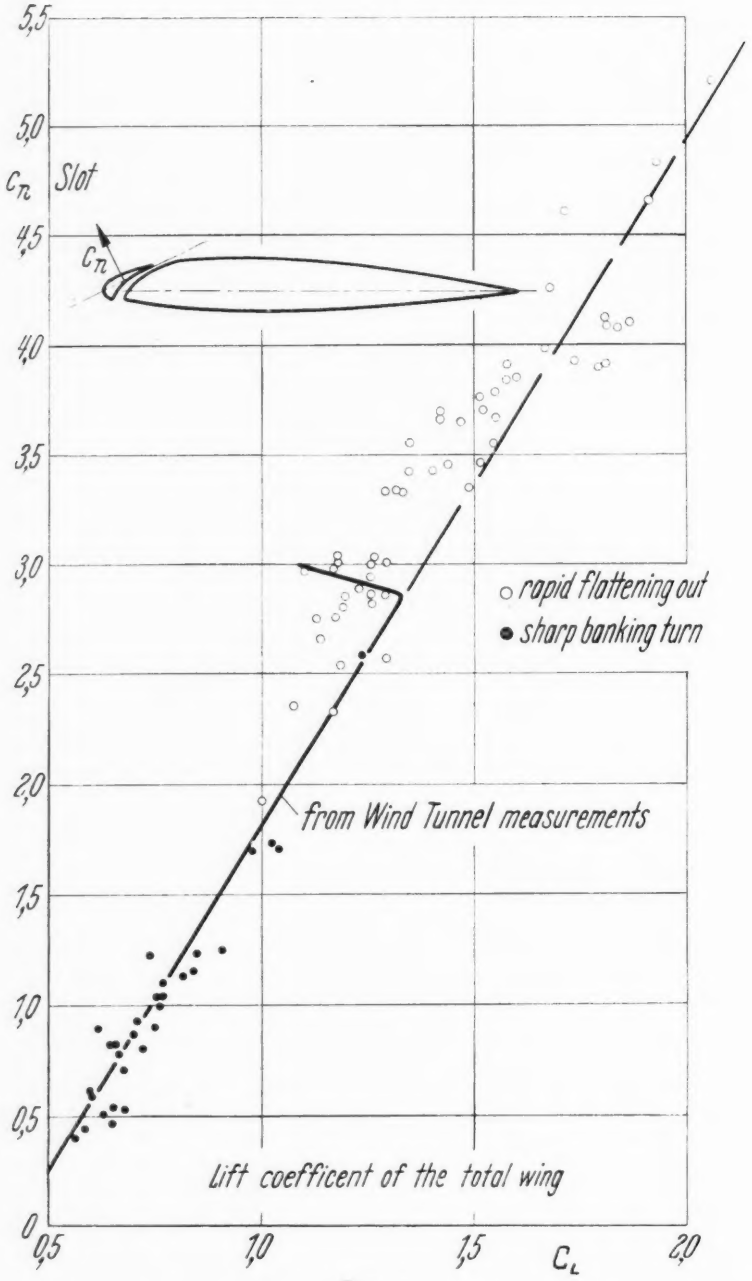



FIG. 4

*Coefficient of the force normal to the chord of a Handley Page slot, in relation to the lift coefficient of the total wing.*

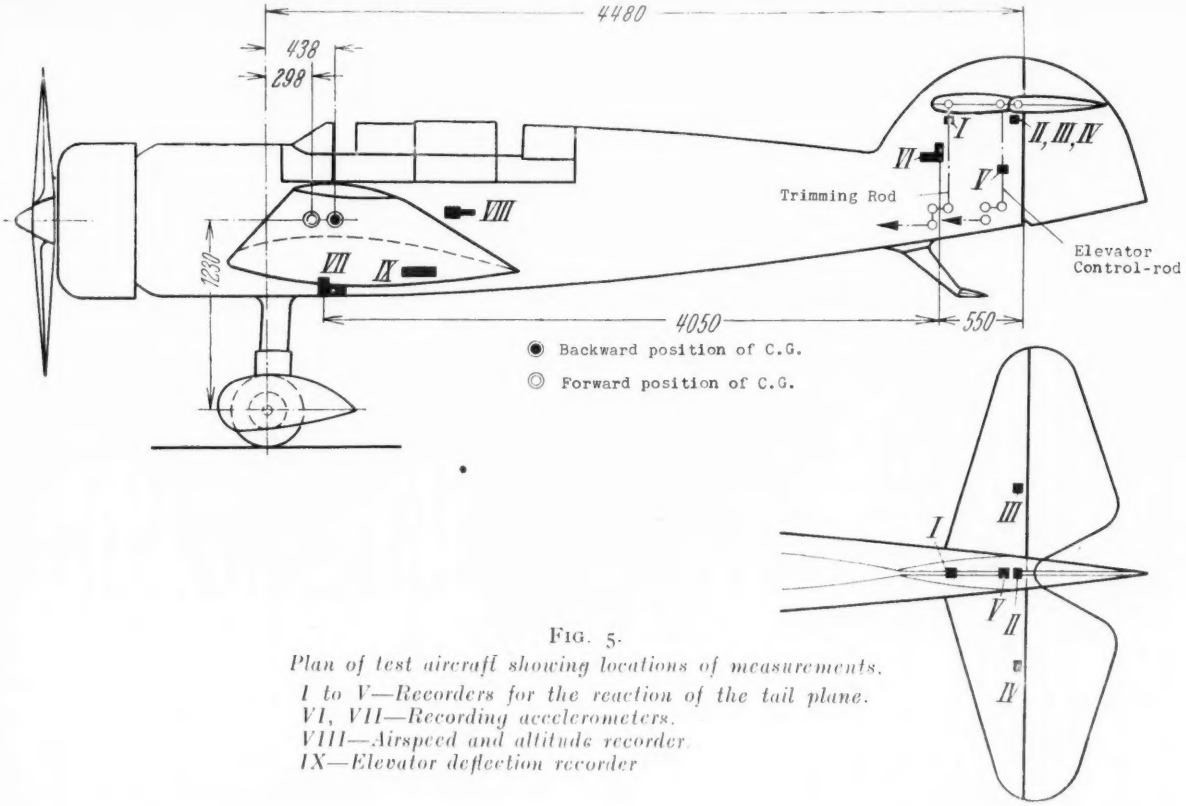



FIG. 5.

*Plan of test aircraft showing locations of measurements.*
*I to V—Recorders for the reaction of the tail plane.*
*VI, VII—Recording accelerometers.*
*VIII—Airspeed and altitude recorder.*
*IX—Elevator deflection recorder*

curves correspond to this value. The upper three curves apply to the extremely slowly revolving airscrews of large diameter, and the lower three to fast revolving airscrews of relatively small diameter. It will be seen that, for airscrews with revolutions and diameters normal to modern practice, the attainable efficiency is at its maximum when $v/v_R$ is approximately 0.55. Since the resultant tip speed cannot be increased at will, and generally cannot exceed 0.85 to 0.9 of the speed of sound, because otherwise the efficiency drops away owing to the compressibility of the air, a definite ratio $v/v_R$ corresponds to a definite speed of flight. For example, if it is supposed that the resultant speed at the airscrew tip amounts to 290 m./s. (*i.e.*, 0.9 of the speed of sound at 6 kms. height), then the speed of flight is indicated at the lower edge of the scale included. From this it will be seen that the efficiency of the airscrew, up to a speed of flight of some 550 km./h., improves with increasing speed of flight. With further increases in the speed of flight, the efficiency drops away and this deterioration increases rapidly at speeds of over 700 km./h.

The decrease in efficiency is caused, as an analysis of the losses in performance show, by the fact that the energy lost in the rotation of the slipstream, increases very sharply with an increase in the ratio $v/v_R$. It does not appear impossible, however, to use the thrust of an airscrew at speeds of flight even above 800 km./h., if these losses are avoided by appropriate devices, *e.g.*, tandem airscrews rotating in opposite directions and the study of the questions involved appears to me to be very full of possibilities.

In the above mentioned investigation on the prospects of airscrew thrust, the results have been taken into consideration of other new tests, carried out on airscrews, in the D.V.L., to which I will refer briefly. In the first place must be mentioned a test of the indicated efficiency of airscrews which was first made possible, in theory, by the above investigation. In this work, in completion of the work of Goldstein " On the vortex theory of propellers," Proc. Roy. Soc. Lon. B. 123 (1929), pages 440-465, and C. N. H. Lock—V. Jeatman " Tables for Use in an Improved Method of Airscrew Strip Theory," A.R.C. Rep. and Mem. 1674 (1934), the degrees of efficiency have been calculated, and graphs have been plotted for 2, 3, 4, 6, and 8-bladed airscrews and selected ratios of pitch to diameter. I will not explain this work in greater detail, the difficulty of which lies, generally, in the mathematical method, but I will simply mention that such work has been carried out and taken into consideration in the described investigation.

In the sphere of manœuvring stability and the aerodynamic forces occurring during flight, there are some very interesting, but very complicated problems. In all this type of work, it is generally a question of determining the aerodynamic forces and moments in relation to the condition of motion. I will not attempt, in a short section of a lecture, to enter into a discussion on the complicated relationships of corresponding measurements, but I will limit myself to a small, special section which may be described clearly and concisely, namely, those investigations which are undertaken to determine the stresses occurring in flight. Fig. 4 gives the results of such a test, in which the forces occurring on a slotted wing, were measured, when flattening out after a dive or bank.

The reason for this test was, *i.e.*, that we discovered some damage to the slot and its fittings which could not be explained by the forces measured in the wind tunnel. In order to determine the forces occurring in flight, we arranged the slot as a recording extensometer, and so measured the forces in curved flight and in rapid flattening out. By this means the value of the lift of the whole wing was determined by acceleration measurements. In the diagram the lift coefficient of the main plane is plotted on the abscissa, and coefficient of the force on the auxiliary aerofoil on the ordinate. It will be seen from this diagram that the air forces acting on the slot become extraordinarily great in rapid flattening out. Since for rapid alteration of the angle of incidence the airflow does not immediately break away when the stalling angle is exceeded, the air forces

increase the total lift of the main plane as well as the forces acting on the auxiliary aerofoil, to double the maximum value measured in the wind tunnel.

Another investigation of this sort relates to the determination of the forces acting upon the tail unit of an aeroplane. Fig. 5 shows an aeroplane of the type Messerschmitt 29, in which four extensometers were mounted at the tail, so that there was no other connection between the tail unit and the fuselage except through these extensometers, one of which can be seen in Fig. 6. On this occasion the glass-scratching recording type of extensometer, described here in detail seven years ago by Dr. Hoff, was used. I cannot explain the results, but I should like to mention the report which has been published and I may add that the accuracy of the measurements made by this method has proved to be so good, that not only were we able, as originally intended, to measure the large air forces acting on a tail unit during the flattening out process, but also the small forces in steady level flight.

Finally, the result of a long series of stress measurements is given in Fig. 7. The ordinate shows the number of times a definite stress occurred in consequence of gusts, banking and flattening out, in one hundred hours of actual flight.

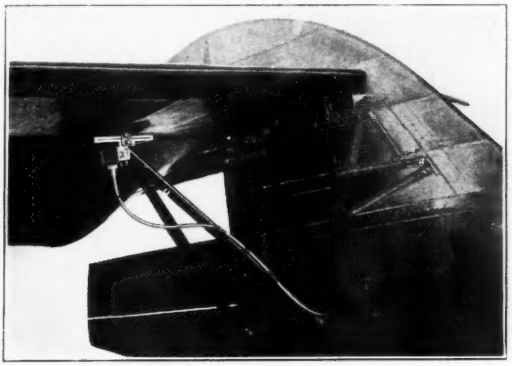
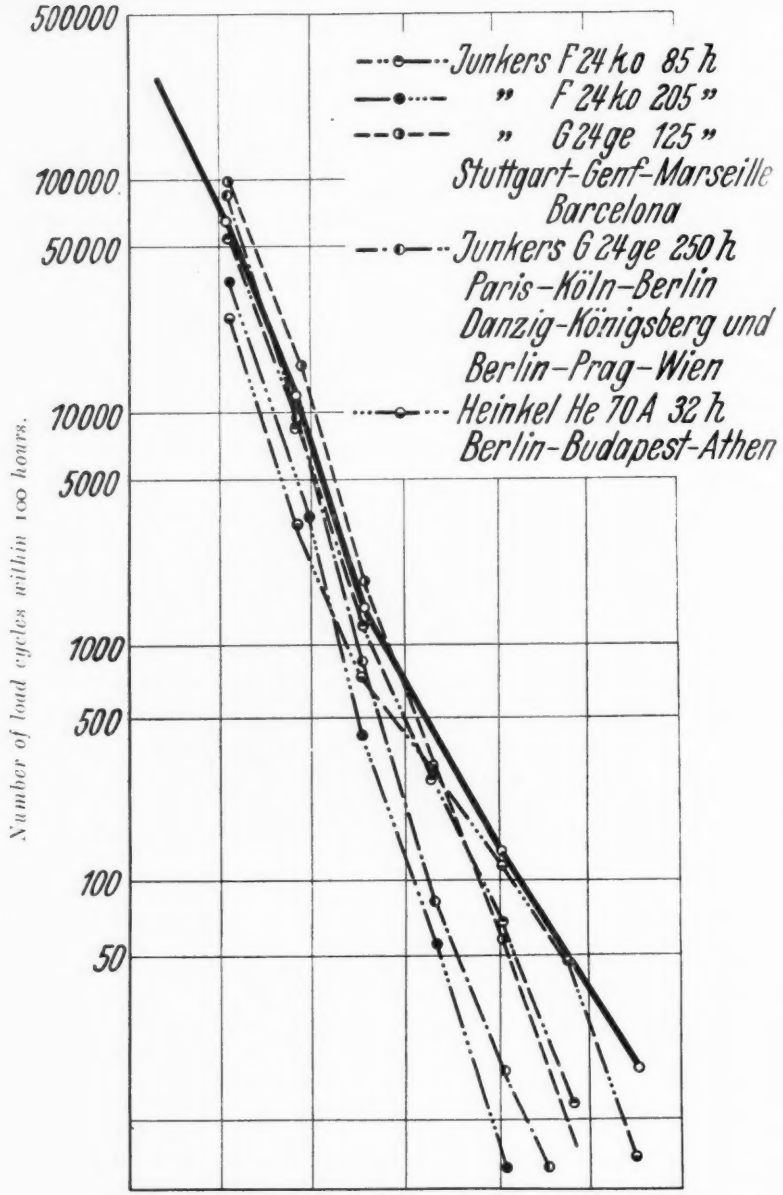


FIG. 6.
*View of tail unit with recording extensometer.*

The magnitude of the load is plotted on the abscissa as a factor of $(n-1)$, where $n$ is the specified load factor according to the German regulations (*i.e.*, with this load factor $n$ the aeroplane must still have a safety factor of 1.8). The broken lines and the points included show the results of measurements which we carried out on various aeroplanes of the German Airways, over normal distances, during 700 flying hours. The continuous line shows the corresponding value obtained by an abbreviated test method.

The number and the dimensions of the stresses obtained in this way serve then, as a basis for research into strength problems. The loads measured during flight are applied with the corresponding frequency to test pieces, such as tubes. It was established from this, as was to be expected, that the sequence of the loads is not unimportant. The number of cycles of the alternating load, which the member will support, is lowest, if the highest load is applied at the commencement and then reduced to the minimum. The member shows an essentially better resistance if the maximum and minimum loads alternate in definite cycles.

Fig. 8 shows the result of such a test on a tube of molybdenum-chrome steel. The two upper curves show the fatigue resistance, which was ascertained in the usual manner, in which a load alternating between two limits, was applied until the test piece fractured. The results are distributed over the region limited by the upper two curves.




*Safety factor* = 1.8. *Ultimate factor* 1.8 *n*.

FIG. 7.

*Comparison of the results of systematic statistics within altitudes up to 600 m. (continuous line) with measurements taken, in operation, by the German Airways (DLH).*

The zigzag (stepped) curve was measured in such a manner, that the various loads, indicated by the steps, were applied always in the same sequence, which corresponds somewhat to the type of load during flight. This was carried out until the tube fractured. In Fig. 8 a mean curve is drawn through the steps and represents the load alternation that this tube would support in the sequence chosen. Finally, the lower curves give the magnitude of the permissible loading, if, with this type of loading, a safety factor of 1.35 is required.

In consideration of the strong relationship between the fatigue resistance and the type of load sequence, it is important that this influence should be examined much more exhaustively in strength tests, even if the above results show that the modern regulations applying to construction seem to be sufficient, on account of the safety factors, to deal with this influence.

In the sphere of strength tests there are, also, the strength of monocoque structures, bending problems, the strength of ready-shaped parts, the question of vibration of aerofoils or other parts of the aeroplane, and similar questions.

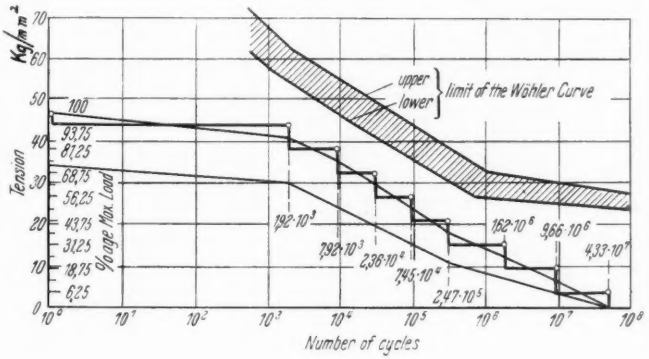



FIG. 8.

*Strength tests, by alternating loading, on a tube of Cr-Mo steel.*

$k_1$ *summation curve of a test in which the test piece is stressed to the limit.*

$k_2$ *summation curve of a loading series which can probably just be supported by the test piece.*

$k_3$ *summation curve of permissible series of loadings if a safety factor of* 1.35 *is required.*

The research problems which are, at present, being treated by the Institute of Aero Engine Research of the D.V.L., are undertaken, on the one hand, at the instigation of the industry for the practical development of engines, and on the other hand, in view of certain general requirements of aeroplane designers, the fulfilment of which is desired in the development of new engines. These general demands, which are required of the development of engines are—(1) increase in cruising altitude, (2) increase in performance with the best possible installation facilities, and (3) increase in range, *i.e.*, the highest possible utilisation of the energy contained in the fuel.

Before discussing the experiments for increasing the cruising altitude, I will mention, next, some experimental tests on the behaviour of aero engines at altitudes. In the year 1936, the D.V.L. began its work in the altitude chamber and since that time, during a total period of operation of the test bed of over 2,000 hours, the behaviour at altitude of five liquid-cooled and five air-cooled aero engines has been thoroughly investigated with the co-operation of the industry, and, moreover, numerous tests have been carried out on individual influences

which determine the behaviour at altitude. Besides the determination of diagrams of performance at altitude, which were placed at the disposal of the aero motor constructors, these investigations have provided acceptable bases for the calculation and design of superchargers and exhaust gas turbines with regard to the consumption of air and gas, and further a basis for the calorimetric calculation and design of radiators for liquid-cooled motors. From these experimental tests, much detailed knowledge has been gained on the influence of the temperature and of the pressure of the air on induction, as well as on that of the exhaust pressure on the volume of air admitted and on the performance of the aero motor.

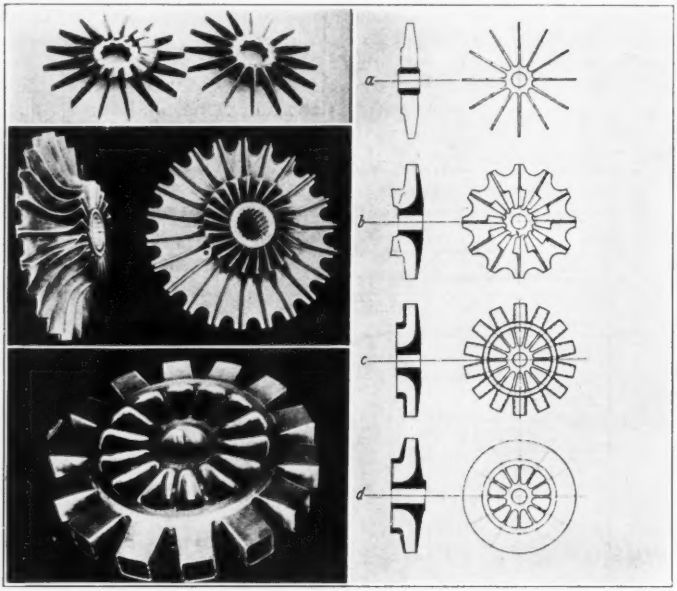



FIG. 9.

*Shapes of rotors for aero engine superchargers.*

(*a*) *Open, star shape.*
(*b*) *Half open rotor (one disc).*
(*c*) *Ducted rotor.*
(*d*) *D.V.L. rotor with discs on both sides.*

By tests on the single cylinder engines of the D.V.L., which were partly conducted under altitude conditions in special plant, it has been possible to continue further and complete the tests made on the complete aero engine. Much research work still remains to be done, before all the important factors influencing the behaviour of engines can be made so clear, that general rules may be established. We are, however, to-day past the stage of groping blindly for the determination of behaviour at altitude, since we have obtained a sound foundation from the experience gained in these tests.

An important part of the work of the D.V.L., which has been spurred on by these observations and experiments, has been carried out in connection with the development of superchargers.

The object of this work on supercharger construction is explained simply by the requirements for the engine arrangement (1) to obtain the highest possible density of compressed air, (2) to retain as low a temperature as possible of the

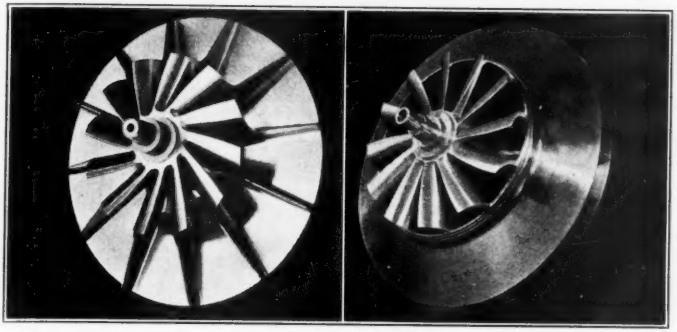


FIG. 10.

*Half open and enclosed on both sides (two discs) D.V.L. rotors with rotating guide vanes.*

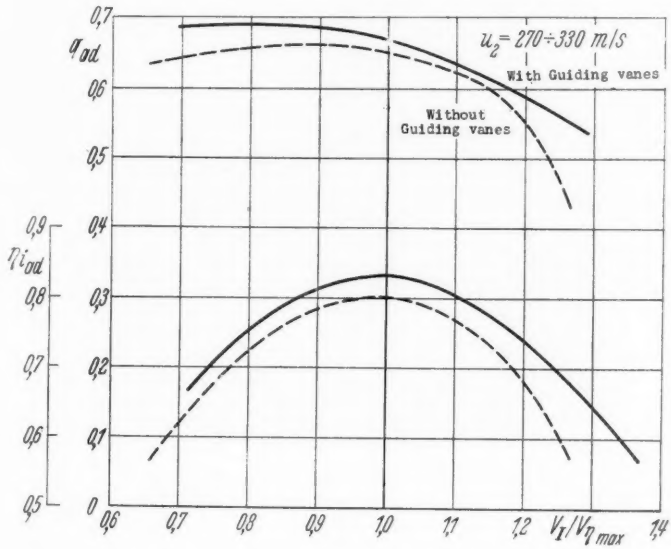



FIG. 11.

*Values of* $q_{ad} = gH_{ad}/u_2^2$ *and* $\eta_{i-ad} = \Delta t_{ad}/\Delta t_e$ *of a new D.V.L. radial supercharger constructed for* 4.5 *kms.,* 1.35 *atmos. and an engine of* 1,200 *h.p. with good operational conditions, over a wide range of peripheral velocities* (270-330 *m./s.*) *corresponding to adiabatic altitudes of* 5,000 *to* 7,750 *m. For comparison, the values of a radial supercharger with outlet guiding vanes and a spiral casing (continuous line) and those of a radial supercharger without guide vanes, but with a spiral casing (broken line) are shown.*

compressed air, with regard to the point of inception of knocking of the fuel being used, (3) to be able so to control the external dimensions of the supercharger, that it can be incorporated in the general construction of the engine in such a way as to secure an aerodynamically good installation of the engine in the aircraft.

In the design of the supercharger itself, it is of the utmost importance to be able to reach the cruising altitude without excessive peripheral velocity of the rotor. It is essential not only to keep the mechanical stresses on the rotor and its bearings within tolerable limits, but also, in order to avoid a deterioration in the efficiency of the supercharger, to prevent the speed of the air issuing from the blower approaching or exceeding that of sound.

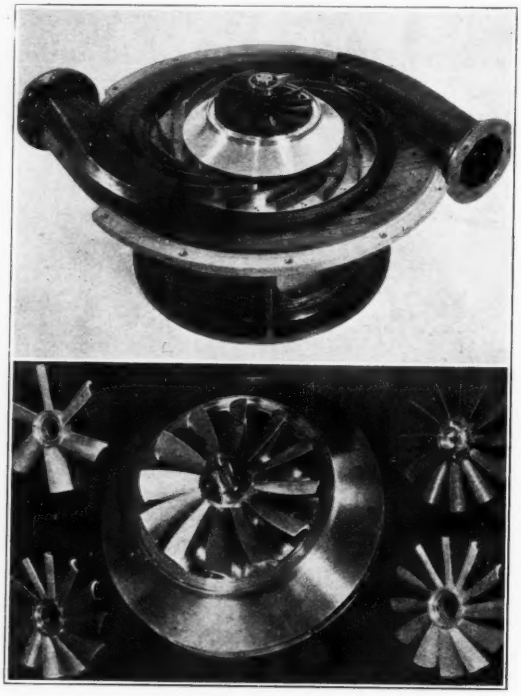


FIG. 12.

*The arrangement of aero engine superchargers.*

The measures taken to realise the above-mentioned requirements extend over the shaping of the air inlet, the rotating guiding vanes, the rotor drive, the number of the impeller blades, the number and shape of the guiding vanes and the spiral casing enclosing them. The practical application of the experience gained by these tests makes it possible, by suitable combination of the steps mentioned, to arrange so that the most favourable range of efficiency corresponds to that of the engine, in so far as the regulation of the engine depends on the variation of the supercharger conditions.

In the course of this work many superchargers were tested, some being of German construction and some from other countries. The influence of the construction of the rotor was examined with special care. Comparisons were made

of the open star-shaped rotor, as has been used for many years past in the Rateau supercharger, the half-open rotor with one disk, which can be regarded as the standard type of impeller construction in all countries and, finally, the closed types of rotor with two disks which, as duct blade rotors, have been used by Junkers in Germany, and which, in another type of construction, highly suited to production requirements, have been developed in the D.V.L. to a high efficiency. These four types are shown in Figs. 9 and 10. The values of efficiency and altitudes obtained with the D.V.L. rotors are shown in Fig. 11.

These experiments were supplemented by tests, on the influence of the shape and number of the blades in the rotor and in the arrangement of the guiding vanes, as well as on the shape of the inlet and outlet ducts. Fig. 12 shows a test supercharger, with variable guiding vanes, a wooden, spiral casing capable of alteration, and the D.V.L. rotor with additional interchangeable blading for the rotating guiding vanes. The greater part of the tests were conducted with this supercharger. These investigations are now so far completed, that reliable data can now be obtained for the calculation and arrangement of supercharger casings, rotors, and guiding vanes. On the basis of these results it is possible to attain constant pressure up to 10 kms. altitude with a single stage, and without having to arrange for the cooling of the compressed air before admission into the motor. A series of experiments has, however, been devoted to the multi-stage, particularly the two-stage type of supercharger, and they have been directed particularly to the possibility of using the thrust on the spindle, to the development of return ducts between the individual stages, and to agreement between the characteristics of these stages.

For higher maximum output altitudes than are usual to-day, and particularly for long-range aero engines, driving the supercharger by means of an exhaust gas turbine would be worth while. The difficulties opposing the construction and operation by exhaust gas turbines lie, in the first place, as is already well known, in the control of the high temperatures which occur if the hot exhaust gases are admitted directly to the blading.

TABLE I.

TENSILE STRENGTH (LONG TIME TEST).

| No. | Material Specification. | 600° | $\sigma 1/300$ in 650° | kg./mm.² at 700° |
|---|---|---|---|---|
| 24 | D.V.L. 325a | >42/45 | — | — |
| 22 | D.V.L. 321 i | 38.0 | — | — |
| 18 | P 193 | 38.0 | 24.0 | — |
| 23 | D.V.L. 321a | 34.0 | — | 17/18 |
| 9 | S.A.S. 8 | 30.5 | >18.5 | — |
| 21 | D.V.L. 32 (22) | 30.0 | 17.6 | — |
| 11 | A.T.S. | 28/29 | ~18.0* | — |
| 20 | D.V.L. 22 | — | 17.0 | ~13* |
| 4 | D.V.L. 4 | — | — | 14.0 |
| 10 | A.T.S. | 25/26 | ~20.0 | — |

* Not determined exactly.

I should like, therefore, to give here a short report on the development of forgeable materials having a strength as great as possible at temperatures over 580°C. and up to 800°C. These materials were really developed in the first place for valves of engines subject to heavy loading, but the results apply as well to parts of exhaust gas turbines. The materials, in order to be suited to long periods of operation, must be of a complete uniformity of structure at the operational temperatures in order to avoid brittleness, and must have a very low creep velocity. The materials which are suitable, according to the experiments, are, in the first place, austenitic heavy metal alloys of chromium, nickel, cobalt, iron base,

with low iron content, austenitic steels of chromium, nickel, molybdenum, copper, and chromium-nickel bases, with additions of tantalum and niobium. A very important part is played by the preliminary, mechanical and thermal treatment. According to the prospective range of temperatures, the D.V.L. have established, for the heavy metal alloys, 32 different series of additions of niobium, tantalum and titanium. The tensile strengths obtained with long time tests lie, now, between 28 and 45 kg./mm.$^2$ at 600°C. These alloys are also able to withstand the burning effect of the gases of combustion up to temperatures of 1,000°. Table No. 1 shows the results obtained, with some of the alloys of this type, by the D.V.L. and other firms.

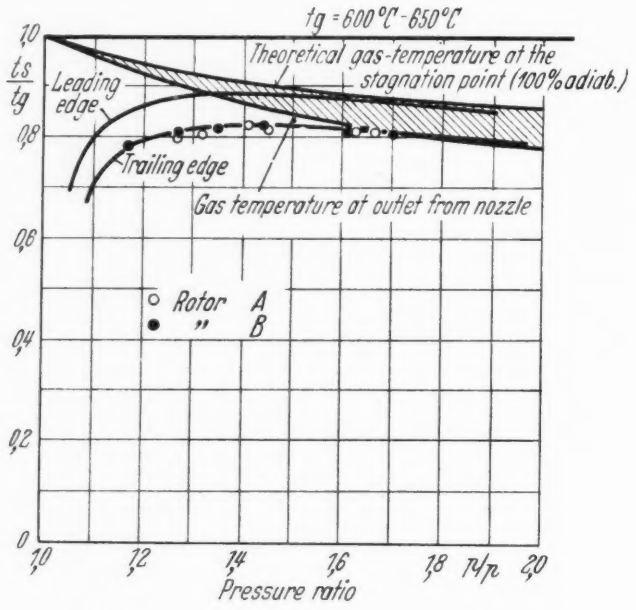



FIG. 13.

*The ratio of blading to gas temperature for a turbine without cooling of blading.*

Although great progress has been made in the production and treatment of heat resisting materials, the strength values obtained at the temperatures in question are not sufficient, in order completely to resist the existing gas temperatures. The efforts of the D.V.L. have been directed, in the first place, towards a thorough explanation as to which methods of operation for exhaust gas turbines offer the best prospects, and which type, in particular, is to be chosen for production, in order to make possible the successful operation of these turbines.

Apart form the thermodynamic condition that the energy available in the turbine is given by the pressure drop and the initial temperature of the working gases, the fact is evident, that the necessary performance of a turbine of good efficiency required for the operation of a given supercharger, is produced either at a high temperature and a low pressure drop, or vice-versa, at a low temperature and with a high pressure drop. Limiting ourselves to the constant pressure exhaust method, which appears to offer, on the whole, the best prospects of realisation from constructive considerations, an attempt must be made to keep the pressure

drop in the turbine as low as possible, *i.e.*, with the working pressure, given by the cruising altitude, behind the turbine, it will be desired to keep the pressure before the turbine as low as possible, in order to be able to utilise, as far as possible in the motor, the pressure drop down to this air pressure. This consideration leads to the requirement of using the highest possible exhaust gas temperatures in the turbine. Our theoretical and practical experimental work must deal next with the question of the temperatures occurring at the blading of the turbine for given gas temperatures, and with the influence of the pressure ratio, *i.e.*, of the cruising altitude and the peripheral velocity of the turbine rotor on these temperatures. As an example, Fig. 13 shows the temperature at the leading edge and the trailing edge of the blades of a test turbine in relation to the pressure ratio of the gas at gas temperatures of from 600° to 650°.

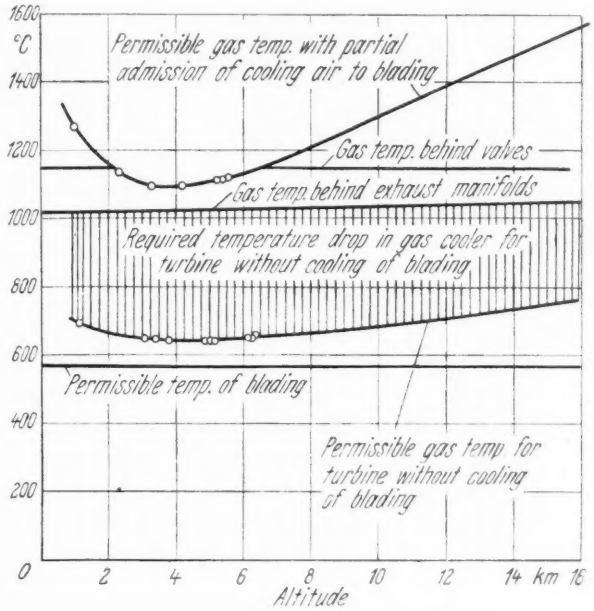



FIG. 14.

*Permissible temperature of exhaust gas for exhaust gas turbines.*

Thus we have to consider the problem of which method offers the best prospects of keeping the temperature of the blading within the limits required in order to retain the necessary strength values. If it is assumed that the highest permissible temperature at the blading may amount to 570°C., then a permissible temperature of the gas before the turbine of 650° is obtained from these measurements increasing with operational altitude up to 800°. This requires a drop of 350° to 500° in the temperature of the gas behind the exhaust valve.

Of the two possibilities of gas cooling, which are (1) the cooling of the gas by mixing with air, and (2) that of surface cooling in a heat exchanger, we are of the opinion that the latter is, thermodynamically, the better. However, the thermal and mechanical loading of the heat exchanger is so great, and so much additional weight and drag is entailed, that the practical realisation is fraught with very great difficulties.

In contrast to these methods of gas cooling, there are those of cooling the rotor. In this sphere we have conducted tests and investigated two possibilities

in particular, in the first of which the cooling of the blading is obtained by the partial impingement of the head wind while, in the second, the cooling is effected by the air which flows through the hollow blading. Fig. 14 shows how much the permissible gas temperature may be increased if cooling air is made to impinge on the rotor over 50 per cent. of its circumference. It is seen from the upper curves, which apply to the process with 50 per cent. impingement of cooling air, that gas temperatures as measured in the exhaust pipes of ignition motors are permissible. Without cooling of the blading, the gas temperature would have to be decreased by the amount shaded.

Fig. 15 shows the corresponding result with the internal cooling of hollow blades. The curve, which forms the lower limit of the shaded section, shows, in relation to the velocity of admission of the cooling air, by what percentage of the temperature difference between the gas and the cooling air, the blading temperature is reduced at the leading edge. With the best shaped blade (on the extreme right in the figure), the maximum reduction in temperature amounts to some 25 per cent. This means that the pressure ratio between the two ends of the blading amounts to approximately 1.8. We believe that we may reach a cooling efficiency by both methods, and above all if they are combined, so great that, in view of the progress made in the qualities of the materials, the cooling of the exhaust gases will no longer be necessary.

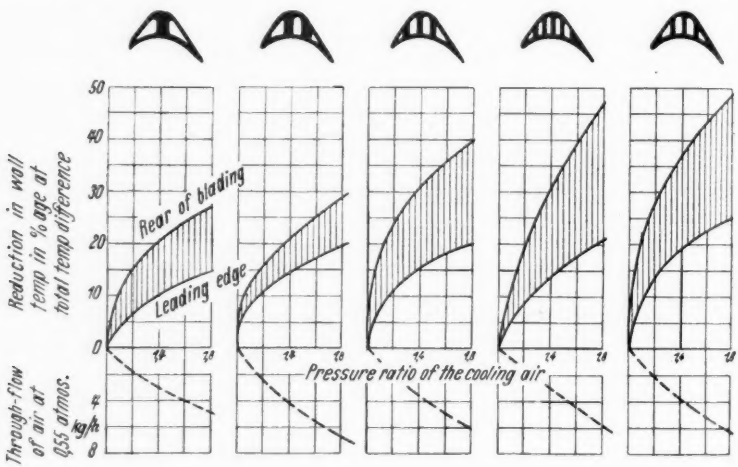



FIG. 15.

*Reduction of the temperature of the blading $\tau$ in percentage of the total temperature difference between the mean cooling air temperature and the boundary layer of the gas, at full impact, for various cooling sections. (Reaction pressure of the cooling air 0.55 atmos. Inlet temperature of air 25°C. Reynolds number at the gas face 23,000. Weight of air in kg./h. per rotor.)*

Of the experiments concerned with the increase in the performance of power units, mention may, next, be made of some tests that were carried out in the investigation of supercharging, scavenging and the conditions of knocking.

For a number of years, much knowledge has been accumulated by the D.V.L. as well as by other research and development institutions in Germany as well as abroad, on the subject of the improvement in performance which may be obtained by increasing the pressure of the charge in four-stroke ignition motors. The

activity of the D.V.L. has, in recent times, been directed, for the most part towards the ascertainment of the thermal limits applying to supercharging.

Other investigations have been carried out into the occurrence of knocking and delayed ignition. On the basis of thermodynamic evaluations, by the use of measurements taken from the pressure curves in motor cylinders and ball-shaped iron chambers, it has been found possible to obtain some very useful ideas regarding these problems.

It has already been mentioned above, that an improved freedom from knocking is possible in the test cylinder by the reduction of the temperature of the parts in the combustion chamber. It is well known that the exhaust valve is the part, the temperature of which is the highest, and which, therefore, contributes most to the danger of knocking. The inference drawn from this fact, expressed for the first time, as far as we know, by Ricardo, is that sleeve valve engines seem to offer increased freedom from knocking. In connection with experiments concerning increased performance, the D.V.L. has already, for some years, studied the problems of sleeve-valve engines. The contention of Ricardo's, that with this type of construction an increase is possible in the highest permissible compression ratio, was confirmed by the D.V.L. Furthermore, it may be expected, that, in view of the dynamically simpler arrangement of the sleeve-valve operation, as opposed to poppet-valve operation, it may be possible to operate sleeve-valve engines at higher speeds of revolution than the poppet-valve engines. The D.V.L. has conducted some constructive experiments to determine which type of sleeve-valve construction offers the best prospects of success in this respect, in order to commence work of the development of certain types.

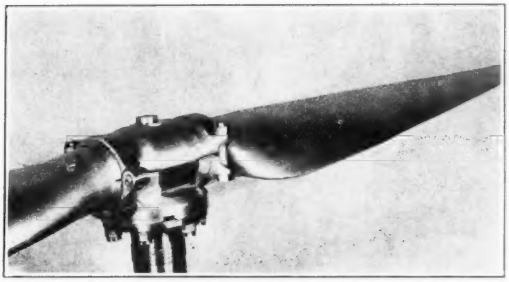


FIG. 16.

*Extensometer at the root of a vibrating airscrew.*

In connection with experiments on engines, arising from increased performance, a whole series of tests has been or is being made in the sphere of fuel stuffs. These experiments have as object. in the first place, the development of such fuels and lubricants as will make possible, with ever increasing engine performance, operation free from all disadvantages, and, this applies mainly to lubricants, which will ensure long life for the engine.

In conjunction with the experiments concerning increased performance, mention must be made of the research into the component parts of power-units, which have as object, the reduction of their mechanical stresses, and the increase in the ability of the parts to support high loads. With increasing operational pressures and speeds of revolution, which will presumably be increased still further, these static and dynamic problems gain more and more importance.

A wide and important section of these experiments is concerned with the theoretical comprehension of the vibrations in the crankshaft-airscrew system. For the type of vibration with degrees of freedom, torsional vibrations of the crankshaft and bending vibrations of the airscrew which occur most frequently

nowadays, there exists a very good theoretical explanation. But the existence of a good theory does not do away with the necessity of instituting a means of technical measurement in order to establish the magnitude of the vibrational stresses during operation. In the theoretical experiments as well as in the tests in this sphere, we are following quite similar ways to those of Mr. B. C. Carter in Farnborough. In the course of the past few years a valuable means of taking measurements on revolving airscrews or crankshafts was discovered in the shape of a suitable dynamic extensometer. The apparatus works according to the carrier frequency method. It has a measuring length of 10 mm. and weighs only 0.5 grams. The extensometer is shown in Fig. 16 fastened to the root of an airscrew.

It is also used, however, for tests on other engine parts, *e.g.*, for the measurement of the stresses on the crankshafts of motors in operation. The fastening is achieved by means of a suitable adhesive material. In view of the very small weight of the measuring apparatus, this method of fixing is sufficient to withstand the centrifugal forces even with fast rotating parts.

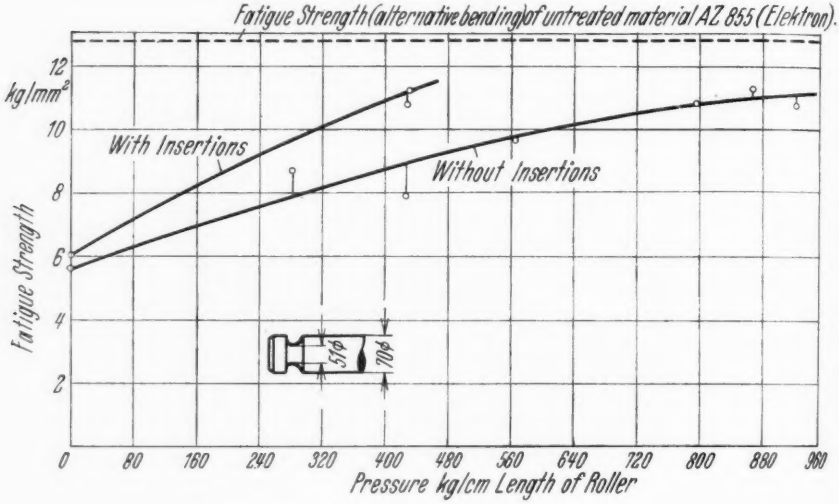



FIG. 17.

*Increase in the fatigue resistance by cold rolling and insertions.*

The problem of airscrew vibrations can to-day be considered as solved at least from the point of view of research by the introduction of the two degrees of freedom, the torsional elasticity of the crankshaft, and the bending elasticity of the airscrew. The theory also shows the way in which the danger of vibration may be efficiently overcome. The vibration problems of the crankshaft-airscrew system are, however, by no means settled and if increased numbers of revolutions are taken into consideration it is to be supposed that future development will have to rely on further degrees of freedom. There are already many indications that the degree of freedom of the longitudinal and bending vibrations of the crankshaft, particularly for radial engines, require thorough consideration. Attention is being drawn, also, to other component parts, such as crankcases and valve-springs, among others, owing to resonance phenomena.

In connection with these investigations attempts are being made to increase the durability of crankshafts, airscrews and the other parts of the power unit by means

of suitable measurements and shaping, as well as by the appropriate choice of materials. An example of the very good results obtained from some of these tests is given in Fig. 17. The lower of the two curves shows the increase in strength obtainable by cold rolling of the airscrew shaft. By inserting intermediate plates between the blades and the boss in order to prevent frictional corrosion, it is possible, as is shown by the upper curve, to increase the durability of the blades, which in this case were of Elektron, to nearly twice the original value.

Of the numerous experiments concerned with the more complete investigation of special long-range power-units, a section applies to the heavy oil motor and another section is occupied with the reduction of the fuel consumption figures of the normal ignition engine to such a level that they will be able to compete with those of the Diesel engine. Comparisons based on sound experience have produced the following data on the possibilities of use of the two types of power-units mentioned, for long range operation; the possibilities of the two-stroke Diesel motor appear to be favourable for flight at medium altitudes, while for high altitudes, the ignition motor developed to give economical operation, as well as the four-stroke Diesel motor, both with exhaust gas turbo superchargers, promise successful application.

FIG. 18.

*Photograph of a jet of fuel (centre of jet) in transmitted light.*
*(Magnification approx.* 5.)

Of the great number of experiments on the subject of Diesel engines, concerned with the possibilities of supercharging and behaviour at high altitudes, I should like to mention one section in further detail. This includes those experiments on the atomisation of the jet of fuel injected into the combustion chamber, the distribution, the dimensions and the speed of the individual fuel particles. Full knowledge of these phenomena is of decisive importance for research into the thermal and chemical processes which lead to ignition.

For the purpose of these tests, the D.V.L. has devised an arrangement by means of which it is possible to take macroscopic, as well as microscopic photographs of the fuel jet. The device consists of a forced spark-path from the injection pump over a Thyratron, the discharge period amounting to approximately $10^{-6}$ sec.

Fig. 18 is a photograph of a jet of fuel, taken in the transmitted light. The photograph shows the distribution of the different sized drops in the jet. The velocity of the drops may be determined from their length in the photograph. It will be seen that the velocity in the centre of the jet is greater than that at the edges. A greater enlargement (Fig. 19) is used for the more precise determination of the drop velocity. The comet-like shape of the drops in these photographs is to be attributed to the afterglow of the spark in the decreasing light path, in consequence of which the full diameter of the drops is not shown on the plates. Fig. 20 illustrates another section of the jet.

The enlargement is the same as in the preceding picture and the photograph represents a section of the edge of the jet, in which the density of the drops is considerably less than in the centre, as was seen in the previous photograph. On the basis of such measurements it can be shown that self ignition of the fuel takes place at the edge of the stream. It is enlightening that the result of this investigation facilitates the analysis of the ignition mechanism in the thermal and chemical processes.

The description of these tests concludes my discussion of the research on power units.

FIG. 19.
*Photograph of the edge of a jet of fuel in a dark field.*
(*Magnification approx.* 30.)

Some of the problems treated, so far, have been dealt with in rather more detail than is within the scope in a lecture of this character, which should give a general survey over a wide sphere. I have done so, because the visitors from your country who were guests of ours in Adlershof, showed particular interest in these subjects. Therefore, I ask for your understanding if I shorten the description of the third and last section of our work accordingly.

This branch embraces all problems on navigation, technical equipment, aerial photography and finally those on the effects of flying on health.

In the course of past years, navigation has relied, more and more, on wireless methods. In consequence, a large part of our work has been connected with the development of wireless navigational processes with the highest possible accuracy for all distances. Some experiments of general interest were accordingly carried out, for example the behaviour of the Ionosphere was examined over

very great distances on short wave-lengths. Zenith reflection measurements were carried out simultaneously at different places and showed no oscillatory connection with the concentration curve of the Ionosphere, but it was seen from the comparison of the distances that, on the average, an apparent depth of layer of the Ionosphere of between 300 and 400 kms. is to be supposed over a long range. This seems to indicate that a multiple reflection of the waves takes place, and that a constant deflection of the waves is not to be assumed.

Further, an investigation was made into the possibilities of those direction-finding units carried on board which are free from night effects and especially the Adcock unit which was built in the form of a co-axial double frame as open aerials cannot be used in the aeroplane. The navigational bearings obtained over long distances gave errors of less than two degrees in 50 per cent. of the cases, and less than six degrees in 98 per cent. of the cases. It is suspected that these errors are to be attributed to the deflection of the waves away from the plane of the great circle.

Extensive tests were made also on the electrical charges of aeroplanes and the prevention of the interference with the wireless reception caused by them. The prevention of these disturbances is becoming constantly more important because with the increasing practice of bad weather flying the frequency of the disturbances during flight through clouds has increased considerably and the effective prevention of interference is now urgently required.

FIG. 20.

*Photograph of the centre of a jet of fuel in a dark field.*
*(Magnification approx. 30.)*

These problems have added significance in Germany, as it has been proved that aeroplanes, fitted with Diesel motors, in flight through dry air, especially above the clouds become heavily charged owing to the high content of suspended material of the exhaust gases. These charges do not differ electrically from those caused by showers of snow or rain, they cause the same interference. By the use of such Diesel-powered aircraft the D.V.L. was in the enviable position of being able to produce the disturbances under test in clear air and to reproduce them every time without having to fly in bad weather.

The solution of the problem consists of the fitting of finely etched points of tungsten to the end of the trailing aerial. These points have the property of conducting the charges away smoothly over a wide region, thereby avoiding interference. Therefore the trailing aerial must be bonded with the

body of the aircraft somewhere above the coupling coil of the wireless apparatus. The trailing aerial must be at least 10 metres or more in length as the points do not give the required discharging effect if too near the body of the aircraft. The tests proved that the points of tungsten are capable of conducting away currents of the order of $10^{-5}$ amps., generally free from the disruptive interference phenomena, and that the spark effect of such discharges by the points is small in mixtures of hydrogen and air.

The measurements made on the charging of aircraft by the dropping of fuel, showed, in a preliminary test on models, no charge, the intensity of which would be sufficient to cause ignition under existing conditions.

As a further result of the work on protection from interference, the following may be added; in testing for interference originating at some distance from the place of reception, it was shown that it is caused, generally, by large, high-frequency, therapeutical apparatus (with a power of some few kilowatts) at sufficient altitude, at distances up to 50 kms., especially on ultra-short waves. Proposals for the prevention of interference by this type of apparatus have been considered, with the co-operation of the German Post Office, for the whole of the German Reich. The screening of such apparatus is to be desired in all countries.

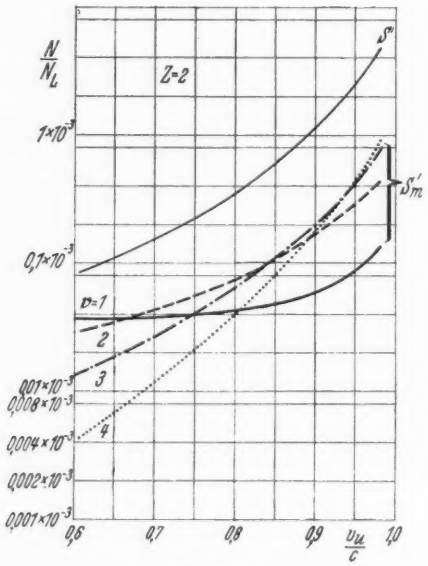



FIG. 21.

*Mechanical acoustic efficiency of airscrews.*

Some results were also obtained on the subject of the reduction of noise in aeroplanes. Of the sources of noise in the aeroplane, the airscrew and the motor, the airscrew has lately received particular attention after the possibilities of the prevention of the exhaust noise were explained at least in principle. The investigations which were made, at first with model airscrews, and later with the airscrews of aircraft in flight showed that there is a very close connection between the noise produced by an airscrew and its aerodynamic performance and its dimensions. The thickness of the profile of the airscrew blade causes acoustically a symmetrical disturbance which is propagated as a sound wave, mainly in the plane of the airscrew. On the other hand the thrust causes an unsymmetrical disturbance,

and the sound produced is propagated in two directions which are inclined at a given angle forwards and backwards from the plane of the airscrew. With the comprehension of these conditions it has become possible to calculate, at least approximately, the noise from the dimensions and thrust of the airscrew.

The tip speed has the strongest influence on the noise produced by the airscrew. If the sound power is expressed in terms of the aerodynamic performance,

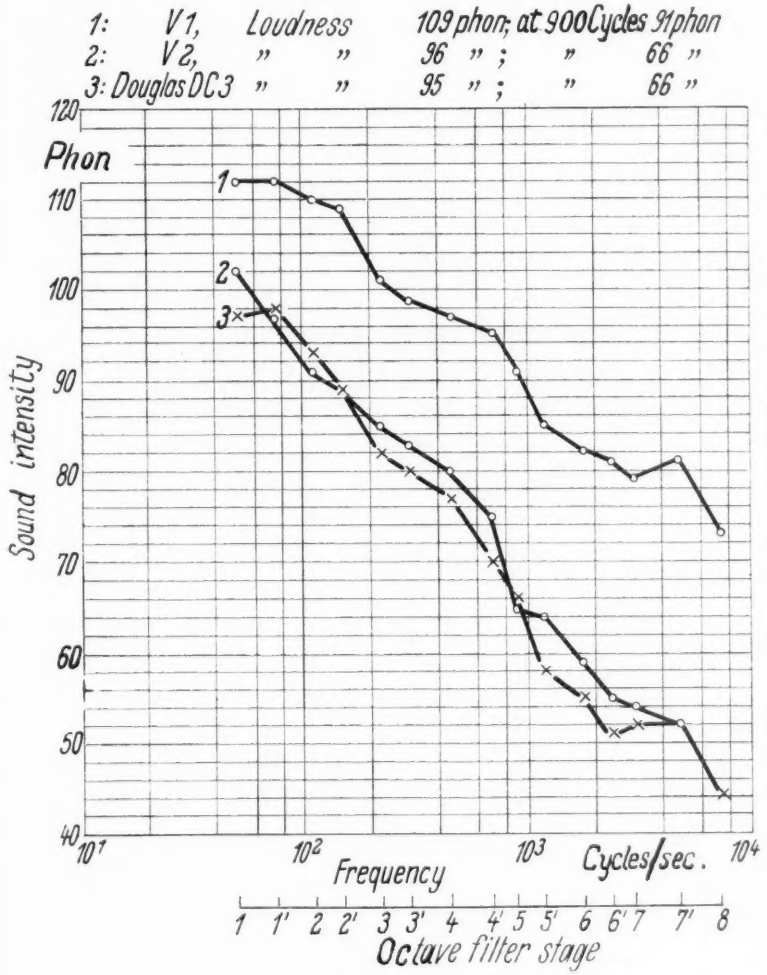



FIG. 22.

*Comparison of the sound-pressure in the passenger cabin of various aircraft.*

*Cruising speed (according to measurements taken by the German Airways) (DLH).*

1. $V_1$ = Focke Wulf 200 without covered walls of the cabins
2. $V_2$ = Focke Wulf 200 with covered walls of the cabins.
3. Douglas DC 3.

then we obtain an acoustic mechanical efficiency which may be used to signify the acoustic value of the airscrew. The upper curve in Fig. 21 was obtained from this efficiency for a series of the airscrews used in Germany. According to this the acoustic mechanical efficiency amounts to about $1^0/_{00}$ (per mille) and varies according to tip-speeds of 200 to 320 m./s. from 1 to 30. It can be seen from this how important the reduction of the tip-speed is for the reduction of noise. Further measures for reducing noise consist of the diminution of the profile thickness and the increase in the width of the blade. The curves $v=1$ to 4 in the figure represent the acoustic mechanical efficiency of the fundamental tone, and of the first three overtones of the noise of the airscrew.

The sound power produced by the motor corresponds roughly to the mean tip-speed of an airscrew so that for high tip-speeds the noise of the airscrew predominates and for low tip-speeds that of the motor.

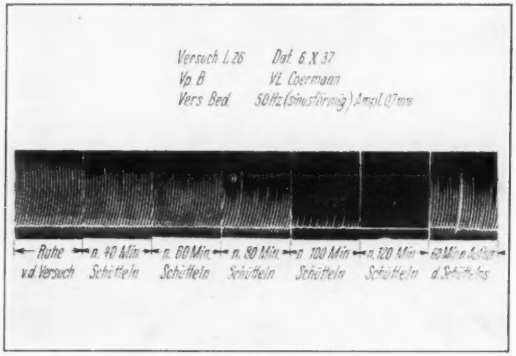



FIG. 23.

*The behaviour of the patellar reflex during a two hours' vibration test.*

The reduction of noise in cabins can generally be obtained only by increasing the absorption since increasing the isolation can be effected only by considerable increases in weight. Improved absorption was brought about by covering the walls with material which was selected from many others after tests in the laboratory. The pieces of material were glued on to perforated sheets of plywood and can, therefore, be used in the construction. The production of acoustically isolated aeroplanes was undertaken in conjunction with the German Airways. Particular use of the results was made in the new German types FW 200 and JU 90. Besides the wall covering the covers of the upholstered seats, the carpet and other fittings, all increase the absorption. The diminution of the cabin noise amounted to 10 to 20 phon, that is 10 phon for the low and 22 phon for the high frequencies (Fig. 22). The large reduction of the high frequencies has the result of making speech in the silenced cabin much more comprehensible. It is possible, without effort, to make one's self understood at greater distances.

On the subject of astronomical navigation some theoretical and experimental work was carried out for the development of artificial horizons, with compensation of the acceleration effect.

Further experiments were made on the regularity of operation of automatic pilots as well as for the improvement of the apparatus required on board. Some experiments were also devoted to the influence exercised by periodic accelerations and shocks on the apparatus carried both with regard to wear and damage as well as to errors in indication. Other tests were made on electrical instruments and the determination of calculation processes with special regard to the latest magnetic steels.

In the sphere of photography we have worked for an increase in the sensitivity of autochromatic and panchromatic plates and those sensitive to infra-red, and for an improvement of the stability of supersensitive emulsions.

In conclusion, I should like to mention briefly that branch of our work which deals with the investigation of the effects of flying on health. Our work in this sphere has been directed solely to the acquirement of that experience which is necessary for the correct selection of the flying personnel and which may help to maintain and improve the capabilities of the flying personnel.

Special attention was paid to the detrimental effect of the pollution of the air available for breathing by the exhaust gases on the faculties of the crew. As the most important result of the investigation, it appears that while for air which is completely free from CO. the detrimental effect on the faculties occurs at approximately 5,200 m., this effect commences at 3,000 m. if the breathing air contains 0.01 per cent. of CO.

Further an examination was made of the influence of noise on the capabilities of the crew, and tests were carried out on the influence of accelerations on human beings mainly with regard to how their resistance to the effects of accelerations may be increased by the appropriate arrangement of the seats and by other means.

As a last example I should like to give the result of a test on the influence of vibrations on the faculties of the human being. Fig. 23 shows how, in relation to the vibrations, the patellar reflex becomes weaker and may be fully extinguished.

This brings me to the end of my lecture. According to your request I have attempted to give a general survey of the work of the D.V.L. In view of the many ramifications of the activities of the D.V.L. it is naturally impossible, in the space of such a lecture, to enter into the details of the individual problems and experiments. I know very well, however, that in many cases the manner in which the details of an experiment are conducted is the most interesting and the most important. I believe that the description of the details could best be made if the specialists who work on the same problems in the various institutions and the various countries come together personally and discuss their work.

In the course of past years we have had the pleasure of seeing, as guests in our country, many British friends, and of being able to discuss with them the common problems in all their details. For us such personal conversations are always a pleasure and also a welcome opportunity for scientific discussion. I should like, therefore, to conclude with the wish that we shall often have the opportunity, by reciprocal visits, of exchanging our views and experiences with the scientists and engineers of your country and of helping each other in this way for the progress of aeronautics and science.

## Discussion.

The Chairman: He had gathered that the D.V.L., unlike such Institutions in this Country, was managed almost as if it were a private enterprise. Many people felt that there was a great deal to be said for enterprise of that kind in aeronautical work.

Sir Henry Tizard, K.C.B., C.B., A.F.C., F.R.S. (*Fellow*) (Chairman of the Aeronautical Research Committee): He accepted with very great pleasure the invitation to discuss the paper and the opportunity to express thanks to Dr. Seewald for having visited this Country and for having presented his paper. Sir Henry regretted that, although he had received many invitations, he had not yet been able to visit the D.V.L.; he acknowledged again those invitations and expressed the hope that soon he would be able to pay a visit and to take the opportunity for personal discussion with Dr. Seewald and his colleagues on matters of mutual interest. They in this Country reciprocated heartily the wish expressed in the concluding paragraph of the paper that there would be many opportunities of exchanging views between the scientists and engineers of the two countries by personal contact, for progress in applied science was aided by personal discussion

even more than by writing. Scientists were able to meet in a scientific atmosphere with a common interest, feeling that they were all engaged in achieving a common object, and able to forget other things.

The views of Dr. Seewald, as to what could be done in the way of increasing speed if they never knew anything more fundamental than was known already, agreed very closely with the views held in this Country, as the result of experiments. The really interesting consideration was whether there was still anything fundamental to be learned which would lead to big practical advances. No doubt Dr. Seewald and his colleagues felt quite certain, as they did in this Country, that there was still something fundamental to be learned, in spite of the great work of Dr. Prandtl and others of his colleagues, and the work carried out elsewhere in the world. Until they understood more clearly the rules that governed the nature of flow of fluids past solid surfaces, they could not predict practical developments with confidence. At the same time their own experiments were gradually leading them to be more pessimistic about big practical advances arising from a more fundamental understanding than perhaps we were two or three years ago. Anything that Dr. Seewald could say on that matter would be of great interest to scientific people. In particular, Sir Henry said that he was less hopeful than he used to be about the control of the boundary layer.

Engine development was in a very interesting stage. He was impressed by the development of superchargers in Germany. So far as he knew we had not yet succeeded in maintaining atmospheric pressure up to 10 kilometres altitude with a single-stage supercharger.

He had often felt that the comparative lack of progress in the development of compression ignition engines for aircraft in this Country was due to the fact that they had had nothing like so much practical experience of those engines as had the German engineers. They did not wish to face the dangers and difficulties of developing a new type of engine unless they were fairly certain that they would get a good deal out of it. One important difference between the compression ignition and the spark engines was that in the compression ignition the maximum pressure could be controlled by the rate of fuel injection, whereas in the spark engine it was controlled by the compression ratio. It had always appeared to him that the more the initial pressure could be increased economically and efficiently by supercharging, the more attractive the compression ignition engine became from the point of view of civil aviation. But so far as he could see, Germany tended rather to revert to the spark engine than to develop the compression ignition engine, in spite of advances in supercharging and the long experience of the latter in Germany. It would be interesting to hear Dr. Seewald's views on that matter.

A statement in the paper which did not agree with experience in this Country, was to the effect that experiments had shown that for high altitude operation the spark ignition engine had advantages over the compression ignition engine.

Dr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc. (*Fellow*) (Chief Technical Officer, Air Registration Board): He was particularly interested in the criterion which Dr. Seewald had used in connection with the drag coefficient of aeroplanes, and he asked for a little more detailed information about the wind tunnel models mentioned in the paper, the drags of which were compared with the theoretical minimum. There was a difference of 30 per cent. between the theoretical minimum and the figure achieved with the smooth model, and perhaps that was due partly to error in the theoretical calculation, because we still did not know sufficient of the fluid flow. He asked whether that was so in fact, or whether Dr. Seewald considered that the difference of 30 per cent. was due to other effects, such as interference. If the models were models of real aeroplanes, that might be the case, of course, and it might still be the case if the models had corresponded to the theoretical assumptions, for example, in having fuselages of the best airship shape. The experiments had led to the figure of 1.3 as the basis on which to compare real aeroplanes with the ideal, and that had suggested, as Dr. Seewald had

said, that they might expect to increase speed in the future only by about 10 per cent. But, as Dr. Seewald had indicated later, there were still means of increasing speed other than the fundamental physical change in fluid flow which it was hoped to achieve. For example, presumably the models were models of fuselage aeroplanes, and there was still the possibility of a change in aeroplane form; there was still the possibility of the tailless type of aeroplane, in which, for a given wing area, there could be a reduction in total wetted surface. There was also the possibility that as aeroplanes were made bigger there would be less reason to have so large a proportion of fuselage area to wing area; and they might achieve better results on bigger aeroplanes than on small ones. Dr. Roxbee Cox did not suggest, of course, that Dr. Seewald had omitted to consider those rather obvious possibilities; indeed, later in the paper reference was made to another one, the effect on speed of increasing wing loading, and some very interesting curves had been given showing that from the theoretical point of view it was not worth while going too far. It was suggested by Dr. Seewald that by the time they had reached a wing loading of 200 kg. per square metre (equivalent to something like 50lbs. per sq. ft.) perhaps there was not a great deal more to be gained. But there again, one imagined that he was considering an aeroplane of the geometrical form they knew to-day, and if there were a tendency to smaller fuselages, the figure of optimum wing loading would tend to rise. Dr. Roxbee Cox believed that the optimum wing loading in practice would not necessarily be that which was indicated theoretically, but would be determined by the consideration of whether the load which the aeroplane could carry could be accommodated in the volume available to carry it. In other words, in the end the optimum would probably be defined by the influence of such practical factors as headroom and the specific densities of men, fuel and freight.

Commenting upon Fig. 7 in the paper, in which the frequency of the occurrence of loads in flight was plotted against roughly the size of the load, he said it would seem that for a number of aeroplanes, each of which flew for 700 hours, there never was an acceleration appreciably in excess of the highest assumed in design. That was a very striking result. He would like to know in terms of g. what the accelerations experienced were, and he asked whether Dr. Seewald had made any co-relation of the loads in the diagram with the weather conditions obtaining during the flight; the Martin Clipper on the San Francisco-Hawaii service not infrequently experienced a total acceleration approaching 3g. and on one occasion it had actually exceeded $3\frac{1}{2}$g.

A sentence which impressed him in the early part of the paper was to the effect that experiments were made by the D.V.L., not in order to attain scientific results, but in order to recognise as soon as possible the future development and the problems arising from it. In other words, they defined the goal, ascertained the problems to be overcome before that goal could be attained, and then proceeded to solve the problems. Dr. Roxbee Cox said that he sometimes wondered whether they in this Country had that point of view sufficiently prominently in their minds, and he thanked Dr. Seewald for having reminded them of it.

Mr. E. F. Relf (*Fellow*) (National Physical Laboratory): Discussing drag reduction and increase of speed, he asked whether Dr. Seewald was studying, as they were studying in this Country, and as the Americans were studying, the boundary layer on wings and bodies in flight in the manner which had been dealt with largely in this Country by Professor Jones, *i.e.*, by measuring the drag of the wing by means of pitot tubes and observing the place on the wing at which the turbulent motion in the boundary layer started. That was a field in regard to which they would like to know very much more than they knew so far. They did not know how the shape of wings influenced that transition phenomenon.

Expressing agreement with Dr. Seewald's remarks concerning the efficiency of present-day machines and the amount of improvement that might be possible, Mr. Relf recalled that in a lecture to the Royal Aeronautical Society he had men-

tioned 30 per cent. drag reduction as being possible by refinements in design, and he was interested to note that that figure was given by Dr. Seewald also. Mr. Relf believed that before long there would be reached a limit of speed which would endure for a very long time, by reason of compressibility effects, as hinted in one part of the paper. That assumed, of course, that there would be no revolutionary discovery. But if they could make a revolutionary discovery which would enable the drag on wings and bodies to be reduced greatly, as for instance, by making the boundary layer remain laminar, they would gain enormously, because they would be able then to attain present-day speed with very much reduced power; that would increase the range of flight on a given amount of fuel and would make commercial aviation an entirely different proposition. Whilst he shared the doubts expressed by Sir Henry Tizard with regard to such a discovery being made, he said it was unwise to dogmatise, for they never knew what was waiting around the corner.

Finally, Mr. Relf recalled with pleasure a visit he had made to the D.V.L. in Berlin a year ago, and said he had been extremely interested to see the work that was being done in that very important and very well organised Institution.

Mr. D. L. Ellis (*Associate Fellow*) (Member of Council): One of the most interesting and startling points made in the paper was that which had been referred to by Sir Henry Tizard concerning the maintenance of atmospheric pressures at altitudes of the order of 30,000ft. The growing importance of nacelle drag was just beginning to impress itself upon them in this Country. In the analysis of drag given in the paper it was pointed out that the nacelle was the one item in respect of which the drag was very much in excess of what it should be, and Mr. Ellis asked for a little amplification of that statement.

Discussing the financing of the D.V.L., he said that apparently the industry contributed considerably to its maintenance. The implication from that was that the industry appreciated and made use of the work of the D.V.L. to a large extent, and that was a most excellent characteristic. Perhaps if the industry in this Country had to pay more for the research work that was being done in a general way, it might appreciate that work more.

Dr. G. P. Douglas, M.C. (*Associate Fellow*) (Royal Aircraft Establishment): He would be particularly interested in an amplification of the point that the drag of the best modern aircraft was approximately twice the minimum drag deduced from the tunnel tests; he would have expected results less pessimistic from the very best German aircraft. The ratio naturally depended on the standard chosen, and in this case it was the sum of the drags of the idealised model parts as measured in the tunnel. It was possible that the drag of the model parts measured in the D.V.L. tunnel was a little low, owing to the proportion of laminar flow area being greater than in flight. The standard used in this Country for this type of comparison, rather as an arbitrary standard, used to be on the lines suggested by Professor Jones, *i.e.*, a definite value for the skin friction coefficient of 0.004. Recent comparisons have been based on the actual turbulent flat plate value at the appropriate Reynolds number and he would have thought that this was a more severe standard than that mentioned by the lecturer and would give a higher value for the ratio.

Mr. A. N. Clifton, B.Sc. (*Fellow*): Had Dr. Seewald arrived at any conclusions concerning the minimum additional drag that was attainable due to cooling, firstly in air-cooled engines and secondly, in water-cooled engines?

Dr. Griffith: He congratulated Dr. Seewald on the very excellent means by which he had attained supercharging efficiencies of the order of 83 per cent., with pressure ratios in the neighbourhood of 2.4, and said that those who were very closely in touch with supercharger work would realise what a great deal of work that had entailed.

With regard to rated altitude, they in this Country had attained something of the same order on an experimental basis.

With regard to the statement that in the design of the supercharger it was necessary to reach the cruising altitude without excessive peripheral velocity of the rotor, he asked whether that was a theoretical limitation or was based on experimental observations. He pointed out that in this Country superchargers had been run at speeds from 60 up to more than 480 metres per second, and no singularity had been found in the efficiency or performance curve.

Discussing the exhaust turbine or turbo-supercharger, he said that the author had rather discounted the possibility of achieving a tolerable blade temperature by cooling the exhaust gases before emission, and one of the reasons given was that the drag due to the cooling would be considerable. In these days of high speed aeroplanes, however, they were not so much concerned with cooling drag; they were looking rather more towards the possibility of making that cooling drag negative, and in cooling the high temperature exhaust gases, they had ideal conditions by reason of the large temperature difference.

Another question was whether the author had considered the cooling of turbine rotor blades in the supercharger by exposure to the atmosphere, for in that way a considerable amount of cooling had been obtained simply by radiation.

Mr. B. S. SHENSTONE (*Associate Fellow*): What impressed one greatly was that when German firms really wanted valuable information they had to pay for it, and he agreed with Mr. Ellis that when one had to pay for something one appreciated it much more than one did otherwise.

The very high speeds considered in the paper, he continued, were not contemplated in civil aviation either at the present time or in the near future. The graphs of the maximum wing loadings were of interest, for nowadays, with the advent of composite aircraft and other proposals, the ability of an aeroplane to fly did not always depend upon its take-off abilities; therefore, wing loadings of 50 and 70 were quite feasible, and it was of interest to note how well the estimations of other people checked with our own.

Mr. F. M. THOMAS (*Associate Fellow*) (Member of Council): He thanked Dr. Seewald not only for the paper, but also for the hospitality that had been extended to him on the occasion of his visit to the D.V.L. in April, 1938. On that occasion, he said, he was conducted by Dr. Laurenbaum around the vibration laboratory, and had been very much impressed by the great amount of work that was being done there in that comparatively new field of investigation. Many machines and complicated arrangements of apparatus were used there for testing structures to destruction, and in one test an actual blade root was vibrated until fracture had occurred. Vibration, he added, was one of the most important structural problems in connection with aircraft to-day.

Commenting on a photograph in the paper of an extensometer at the root of a vibrating airscrew (Fig. 16), he asked whether much work was being done now in Germany on rotating airscrews, and he added that in England and in America one firm had checked out the vibrating stresses at any point of a metal blade in flight. He also asked whether the D.V.L. made extensometer stress measurements on parts of engines; did it use extensometers on crankcases and cylinders, and on parts of aeroplane structures which were subjected to applied loads, such as those incurred in landing?

Discussing the limits of speed of flight, he said he believed that as the result of the work and calculations made in this Country, they would agree with Dr. Seewald that the limit of speed imposed by the conventional airscrew as it was made to-day was in the vicinity of 450 m.p.h., and that the limit with airscrews as they could easily be made was about 550 m.p.h. The engine was the first factor limiting the speed of flight, and, therefore, when considering speed of flight, they must simultaneously make measurements of the characteristics of aerofoils in order to find out the shape which gave the best performance at speeds at or just about the speed of sound. Therefore, he asked whether the investigators at the D.V.L. were revving airscrews to very high speeds and measuring the thrusts with different

aerofoil sections, or were measuring the effects of basic shapes of aerofoil in high speed tunnels, or were merely calculating.

Major B. C. CARTER, M.I.Mech.E., A.R.C.Sc., D.I.C. (*Fellow*): He was particularly interested in the extensometer described in the paper. He asked what degree of accuracy could be attained in its use, and whether it was accurate enough to be used for a torsiograph. *i.e.*, by putting it on a helix on the shaft in order to obtain a record of the torque variation in the drive. He also asked whether, in Dr. Seewald's experience, the torque variation in the drive of the airscrew was the major cause of airscrew blade vibration troubles, or whether he had had experience of those troubles arising from aerodynamic causes as well—from proximity to the leading or trailing edge, or aerodynamic unsymmetry in the inflow. Another question was whether he had used the De Forrest methods, or whether the D.V.L. had confined its attention to the particular extensometer illustrated in the paper. In America, he said, investigators used the De Forrest methods, in Germany they used the extensometer of the type illustrated in the paper, and in this Country we had used the optical method. But all three methods were complementary, their use depending on the objectives in view.

It had been very interesting, he continued, at the time he had presented his own paper to the Society, to receive from Dr. Laurenbaum, of the D.V.L., a copy of Herr Meyer's paper, and to note how well the work of Herr Meyer and the work in progress at Farnborough dovetailed together. It was very heartening, whilst the work was in the theoretical stage, to hear of the agreement achieved in the conclusions arrived at.

Finally, he asked whether, in cases where a supercharger was used, the efficiency was such that there was no need for an intercooler between the blower and the engine.

Mr. W. D. DOUGLAS (*Fellow*): He was interested to note that the only work on structural strength dealt with in the paper was concerned with measurements made during actual flight, and said that that work was of particular interest to them in this Country, because they had done very little by way of measurements of loads and stresses in flight. He believed they were often deterred from such work by the difficulty of securing accuracy; but the D.V.L. records on the slot forces had shown that valuable information could be obtained by means of relatively simple apparatus.

Commenting on Fig. 7, showing the frequency with which loadings of various intensities might be expected to occur during normal flight, he said that if it were allowable to extrapolate the curve downwards it would show that the basic strength had been wisely chosen, as in most cases the failing load would not be reached in a period less than that of the probable life of the aircraft.

The CHAIRMAN: With reference to Fig. 4, dealing with the coefficient of the force normal to the chord of a Handley Page slot, in relation to the lift coefficient of the total wing, he said that the 2:1 ratio of maximum force observed in flight to that obtained in steady conditions in the wind tunnel was not new, for they had evidence of that kind from work done in America and in this Country; but he had never quite understood why aeroplane designers had found it possible to regard it with such equanimity as they did. If it were true that all their strength regulations, which were based fundamentally on the idea of flattening out, or some manœuvre which involved that, were inadequate, in the sense that the forces likely to arise were twice as great as those provided for, it was a good thing that a fairly large factor of safety was included.

He asked for further information as to the interpretation of Fig. 7.

Wing Commander T. R. CAVE-BROWNE-CAVE (*Fellow*): Does Dr. Seewald's experience confirm the conclusion widely held in this Country that, even when an aircraft was taking off, the noise of the exhaust was so much less than that of the airscrew that it made no appreciable difference to the total noise heard by persons on the ground?

The CHAIRMAN: Fig. 6 in the paper recalled to his mind some experiments carried out at Farnborough some 20 years ago, when an aeroplane was cut in two at a point just behind the pilot, the two parts being joined together by a hinge and a spring balance, in order to measure the forces on the tail plane in flight. Referring to the view of the tail unit with recording extensometer, in Fig. 6, he said, he presumed that that instrument was the D.V.L. scratch recorder, tied to the link joining the supporting structure to the tailplane, and he was reminded that we in this Country had shown our admiration for that apparatus by buying quite a large number; indeed, they were among the D.V.L.'s best customers. In case some people might be critical about their own apparent inability to produce such a good instrument, he said that where such a superb apparatus was available it was probably more economical and satisfactory to make use of it than to try to develop another instrument in competition with it. If anyone could show him as good a recorder as that of the D.V.L., he would be ready to consider it as a competitor.

On the motion of the Chairman, a hearty vote of thanks was accorded Dr. Seewald for his paper.

Dr. H. SUTTON (*Fellow*) (*Contributed*): The D.V.L. work on forgeable high temperature alloys described by Dr. Seewald is very interesting and in that connection the point arises as to whether the development of these materials has not reached the stage at which the use of cast materials can be envisaged when the working temperatures concerned are of the order of 600°C. or higher. It would be interesting to know Dr. Seewald's view on this point.

As regards Table I, do all the results given in this table represent the stresses to give 1 per cent. permanent elongation in 300 hours at the temperatures concerned? The values given suggest that this is so, but the marking of the different columns in the preprint of Dr. Seewald's paper leave the matter open to conjecture.

With reference to Fig. 17 it is not clear how the lower curve indicates the benefit of cold rolling—presumably surface rolling—mentioned in the previous paragraph unless it is that the shanks tested with insertions were surface rolled and those tested without insertions were not. In that case, however, the advantage due to surface rolling appears very slight.

It is very gratifying to find these interesting modern developments on materials mentioned in a paper covering such a wide range of aeronautical research work.

## REPLY TO THE DISCUSSION.

By Dr. Ing. F. SEEWALD.

(Communicated and translated from the original German.)

First of all I must thank all my listeners for their interest in my paper, and the Chairman and all those who took part in the discussion for their friendly and appreciative words and for the stimulating discussion to which they contributed.

Sir Henry Tizard says he was impressed by the information concerning the development of the supercharger. It appears to me that the results I showed do not reveal anything so very extraordinary, although at first glance this may not appear to be so. The permissible temperature of the compressed air depends, naturally, on the fuel used. With suitable fuel a good engine satisfactorily sustains compressed air temperatures up to about 120°C. At a height of from 7 to 10 kilometres with an atmospheric temperature of from −25°C. to −40°C., a temperature increase due to compression of about 150°C. can be allowed. From this it follows that for a supercharger to function efficiently, its adiabatic efficiency must be equal to or greater than 0.72. If this minimum requirement is fulfilled, then with our present standard of knowledge the question does not become too involved. Two years ago, at the Lilienthal Gesellschaft meeting in Berlin, Mr. Ellor gave a measured result on a Rolls-Royce supercharger which agrees closely with these figures. The numerical values given by Mr. Ellor were: a height of 14,500 metres, when delivering adiabatically at a rotational speed of 485 m./s.,

and adiabatic efficiency 0.7. This supercharger at an adiabatic efficiency of 0.72 with a rotational speed of 400 m./s. could reach the same height. The requirements would also be fulfilled by the use of a fuel of high anti-knock rating.

The main difficulty which still prevents the practical adoption of superchargers with such high efficiencies no longer lies in the supercharger itself, but in the fact that there is not yet any adequate and practically tested device for adjusting the speed of revolution of the impeller during flight. But no doubt something of this kind will soon be developed.

Answering Sir Henry's further question about the development of the Diesel engine, I would say that I do not think there is a tendency in Germany to abandon the Diesel. If one still sees far more petrol engines in Germany, the chief reason is that, wherever you find a desire for standardisation of the power plant installation and uniformity of servicing and overhaul, the established and generally known petrol engine will be preferred. This will probably continue to be the case, for short and medium range use.

On the other hand, we have every interest in the further development of the Diesel engine, and not exclusively the two-stroke cycle. We are entirely in agreement with Sir Henry about the advantages of the Diesel. The question of overloading is a much better proposition with the Diesel than with the petrol engine. The supposition that the consequent warming of the compressed air improves combustion in the Diesel engine is a practical one, and considerably simplifies high altitude running, by comparison with the petrol engine. However, the energy balance sheet of the turbo-compressor at altitude is more favourable for the petrol than for the Diesel engine; consequently the former will always be better adapted to altitude flying.

In answer to Dr. Roxbee Cox, in all probability a comprehensive report concerning the model tests he mentions will soon be published. I think, too, that the difference of 30 per cent. is primarily due to interference.

I quite agree with Dr. Roxbee Cox that, in addition to the boundary layer, other factors lead to the rise in speed; *i.e.*, the reduction of the wetted surface in all-wing aeroplanes. All such experiments on limits of attainable performance are only valid so long as the premises on which they are based are valid. One of the premises on which the tests in question were based, and which is expressed in the forms of the models, is that the shape of the aeroplane should correspond essentially with the modern standard form of cantilever monoplane.

Our object in making these experiments is not to prove an absolute limit of attainable speed. We merely conclude, with every reservation, that many means which have hitherto been adopted to improve performance lead to no further progress after a certain point, and that we must look around for new and still untried means.

I also agree with Dr. Roxbee Cox when he says that the design (*e.g.*, wing loading) is not usually chosen in such a way as to give the theoretical optimum, but from practical considerations, among which the accommodation of loads is paramount. Therefore I do not believe there will be very much increase in wing-loading above the present figures, at least not while the aeroplanes in question are to be used for practical purposes. On the other hand, it would be quite in order for special aeroplanes, where these practical considerations are unimportant (*e.g.*, for a racer) to approximate closer to the theoretical optimum values.

To the question regarding acceleration measurements in flight, I would say that these measurements, which have mainly been taken in co-operation with the Lufthansa, are a check on the gust cases for the strength requirements for aeroplanes. These instructions stipulate that, in designing the aeroplane, a safe load shall be taken as a basis, dependent upon the level speed of the aeroplane, its wing-loading, and the ratio $dC_L/d\alpha$. These figures give the loading which occurs when the aeroplane flies from still air into a vertical up-gust of a given speed (the strength requirement assumes a vertical speed of 10 m./s.). The specified load

so obtained varies according to the type of aeroplane, and the ultimate load for the aeroplane must be 1.8 times the safe load.

The results quoted only prove that the maximum value over a long series of measurements coincides satisfactorily with the specifications, and that therefore the requirements represent fairly well the actual conditions. The highest gust loadings which have ever been measured, and which (as I have just said) are determined by the individual characteristics of the aeroplane under test and not only by weather, are, as Dr. Roxbee Cox agrees, between 3g. and 3.5g. In all these measurements (taken on the Berlin-Cologne-Paris, Berlin-Prague-Vienna, Berlin-Danzig-Königsberg, Berlin-Budapest-Athens, and Stuttgart-Geneva-Marseilles-Barcelona routes) the weather forecast of the ground station was compared with the observations of the crew. It may be reckoned that these observations cover the worst weather conditions which can be encountered in European air transport.

I am glad to note from Mr. Relf's remarks that he has arrived at the same conclusion as we have regarding the prospects of further increases in speed. The methods used in England for finding new means of reducing drag also seem similar to our own.

The question raised by Mr. Ellis has already been answered by me, so far as it concerns supercharges. My statement that " radiators and engine nacelles are farthest removed from the lower limit which can be held as attainable " should be taken as meaning that even the best shapes of engine nacelle hitherto adopted constitute a large part of the total drag in the best types of aeroplane. Considering that it is physically possible to construct radiators which, at least, at high temperatures, create no drag but merely lift, this no doubt is the direction in which improvements can be made.

Dr. Douglas mentions that, in comparing the drag of modern aeroplanes with the hypothetical aircraft of the future, the result depends upon an arbitrary standard. This is doubtless right, and after all it is a matter of taste whether, with this hypothetical aircraft, one assumes as limiting value the frictional resistance of a flat plate or, as we do, that of bodies of finite thickness. But we must bear in mind the following point: the closer one adheres to the generally recognised basic principles of natural science, the surer one becomes that the values of the hypothetical standard of comparison do not alter. On the other hand the more one introduces into the hypothetical aircraft values which admittedly in the present state of technique, but not from the standpoint of natural science, constitute an optimum value, the more convinced one becomes that the propositions advanced will be upset by some new discovery or by some increase in scientific knowledge. In comparing results one must naturally take into account the different places and different conditions under which the experiments have been carried out.

In reply to Dr. Douglas' query of the point that the drag of the best modern aircraft was approximately twice the minimum drag deduced from the tunnel tests, I agree that judgment must be exercised. We consider this figure less important than its logical conclusion: *i.e.*, that even the best up-to-date aeroplanes can be considerably improved without any fundamental changes in construction or new channels of research.

To Mr. Clifton's question concerning cooling resistance I can only repeat that I cannot state a lower limit, but that I believe in the possibility of great improvements.

I found it extremely interesting to hear from Dr. Griffith that no singularity has been found in the efficiency or performance curve when increasing the rotational speed of superchargers up to 480 m./s. This agrees with the result that Mr. Ellor gave us in Berlin. Tests we have made have shown a very apparent falling off in efficiency at these speeds. It is therefore not possible to give a generally valid figure for the rotational speed at which the decrease begins, since Mach's number (proportional to the Reynold's number) depends on the geometric arrangement of

the impeller, on the degree of reaction of the supercharger, and on the temperature of the expelled air. I would, however, suspect that the point at which the efficiency decline becomes very apparent lies at not more than 450 m./s., even for a good supercharger. Besides, the aerodynamical problem is not the only one which confines us to working at lower speeds. The combination of aerodynamic and strength considerations offers problems which become more and more difficult with increasing rotational speeds. For this reason we consider it important to manage with much smaller rotational speeds while obtaining highest efficiencies.

Regarding the question of exhaust coolers I should like to remark that I was thinking of the present state of engineering and of the difficulty in constructing such coolers with sufficient reliability. From the purely physical point of view, the exhaust cooler tempts one to use it for generating thrust. On the other hand it is particularly difficult to find a suitable arrangement for this, while at the same time fulfilling all other requirements; *e.g.*, durability, heat insulation, and avoidance of interference.

In reply to the question about the diffusion of heat by radiation in cooling vanes, measurements have been made on a turbine rotor as illustrated. In the illustration it was shown that 70 per cent. of the heat was conducted away by the cooling air, while 24 per cent. went to the shaft and only 6 per cent. was absorbed by radiation into the casing. If one removed the casing and neglected the cooling effect due to the throwing out of air, the amount of radiated heat which would go into the free space would be considerably increased. The figures shown indicate, however, that simultaneous cooling in this way is not possible.

I agree with Mr. B. S. Shenstone that wing loadings of 200 kg./m.$^2$, or even 280 kg./m$^2$ can be profitable in certain cases. But it is only occasionally worth while to gain a comparatively small increase in speed by raising wing-loading despite the inherent disadvantages.

In answer to Mr. F. M. Thomas, who asks whether the D.V.L. makes stress measurements on an aeroplane and engine parts, I may say that this has been done for several years. Results of such tests, for instance, are the measurements on aeroplanes of the Deutsche Lufthansa in gusts. Strain measurements have also been taken on the undercarriage, rudder-posts and engine mountings, in flight, when landing, etc. Where a method was known, certain measurements had also previously been obtained on running engines. But the strain meter (illustrated) first made it possible to investigate the behaviour of the fast-moving and more inaccessible parts, such as crankshaft, airscrew, etc., during flight.

We also study the problem of airscrews rotating near the velocity of sound, by trying to analyse the test results on propellers rotating at high speeds in the wind tunnel, and by applying aerofoil data for corresponding velocities in the design of the airscrews.

In answer to Major Carter, who asks whether the accuracy of the strain meter is sufficient to justify its use as a torsiograph, I can say that the sensitiveness (for steel) is $\frac{1}{4}$ to $\frac{1}{3}$ kg./mm.$^2$. For a larger meter (measuring length 25 mm.) the sensitiveness would be 1/10 kg./mm.$^2$. The accuracy of the small strain meter is approximately 10 per cent., and that of the large one approximately 4 per cent. A torsiograph working on the principle of the strain meter, as Major Carter suggests, is already under construction. We have, however, measured the torsional vibrations of the rotating crankshaft directly with the strain meter (c.f. Ratzke: "A new Electric Dynamic Strain Meter," 1937: Annual of the Deutsche Luftfahrtforschung, S II/278).

Replying to Wing Commander T. R. Cave-Browne-Cave; where volume of aeroplane noise is concerned, the principle that only the loudest source of noise matters again holds good; therefore no real advantage is gained by damping minor sources of noise.

In general only above a rotational speed of 250 m./s. is the airscrew noise greater than that of the exhaust. If, however, the engine noise is the greater, by fitting

a silencer to the exhaust, one can reduce the total noise by 6-12 phons (as measurements on various machines have shown). Thus a variation in sound intensity is achieved, and therewith a reduction in carrying power to half or one quarter of the original distance.

It must further be remembered that airscrew noise is generated in the plane of the screw, while the exhaust noise is generated in the direction of the longitudinal axis of the aeroplane.

With this I hope that I have answered, in essentials at least, the questions put to me in the discussion. I wish to express my gratitude once more for the friendly reception accorded me, particularly for the Chairman's kind words, and for the extremely interesting and stimulating discussion.

I would like to answer Dr. Sutton as follows: So far we have not used one of the extreme heatproof materials in the casting state, for the following reasons: With casting moulds for more complicated parts, difficulties exist to a greater extent than in normal steel casting. Apart from this, castings, as opposed to forgings, can never with certainty be free from faults—an essential in highly stressed parts. For the best alloys, a forging process always helps towards good creep properties. Stresses at certain temperatures are given in Table I for various materials. These stresses result in a total (elastic and plastic) elongation of 1 per cent. in 300 hrs.

# ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

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*(Prepared by R.T.P.)*

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*Safeguarding Aerodromes from Aerial Attack.* (Air Fleet News, U.S.S.R., Vol. 21, No. 12, December, 1938, pp. 34-6.) (68/1 U.S.S.R.)

An aerodrome is always detected if the enemy can actually watch the take-off or landing of aircraft or if tracks can be seen in the dewy grass or on snow. For this reason flying fields must be made to appear unsuitable by scattering light sand (*i.e.*, appearance of agricultural land) or simulating roads by burning away the grass in tracks. Artificial colouration (dyes) can also be employed.

Attention of the enemy can also be diverted by erecting mock buildings at some distance from the actual landing ground. The buildings can be made of derelict aircraft, empty fuel tanks, etc. Distinctive markings must also be provided to simulate landing instructions, in the hope that the enemy will attack the bait. The characteristic contours of aircraft standing in the open must be hidden by adding material (of the same colour as the ground) to the wing tips and tail surface. In winter unbroken snow surface is easily simulated by white ground sheets. In summer the presence of abundant vegetation also renders camouflage easier. In the absence of much vegetation, however, the difficulties are very great. Matters are complicated by the fact that the normal colouring of aircraft (intended to render them more difficult to detect when observed in the air) gives rise to increased contrast on the ground.

*Some Remarks on Aerial Warfare.* (H. von Rohden, Luftwehr, Vol. 6, No. 1, January, 1939, pp. 2-13.) (68/2 Germany.)

The mass utilisation of a new weapon has always produced far-reaching effects on the tactics of warfare, and the question naturally arises whether the air arm is now in a position to produce decisive results on its own. This is no doubt the case if one of the combatants disposes of great superiority in the air. It is doubtful, however, whether such a superiority will exist in future conflicts, which thus cannot be won in the air alone, but which will require co-operation of all methods of attack.

In this co-operation the air arm is destined to play an important role, especially in the early stages of a campaign. With a fleet, on the other hand, results can generally only be achieved by a blockade, the effect of which can be nullified over a period by the proper organisation of all resources of the blockaded country. The proper use of the air arm will call for great qualities in leadership, uniformly well trained crews, ample reserves in men and material and an efficient ground organisation (aerodromes, signals, A.A. artillery). The ground organisation

especially requires the most careful study, as well as the grouping of the forces in depth and width. The author discusses at some length the relative advantage of a self-contained " air army " which can operate in a similar manner to the mixed brigades first introduced by Napoleon. One very important factor in air fighting is the weather and meteorology thus becomes a military science.

*The Participation of Aircraft in Ground Fighting.* (Gen. Maginel, Rev. Millit. Gen., Oct.-Nov., 1938, Luftwehr, Vol. 6, No. 4, April, 1939, pp. 134-144.) (68/3 France.)

Aircraft can operate either in the front line itself or on the lines of communication. In the case of modern troops provided with ample artillery, the author is of the opinion that participation in front line fighting will be extremely costly and only be justified in exceptional cases. The normal field of application of aircraft is the zone behind the front, and this requires fast medium-sized bombers of great manœuvrability.

The diving method of attack has received considerable attention. It has, however, the drawback of requiring special aircraft and highly trained crews. As an alternative the author favours low altitude horizontal attack. By making suitable use of the terrain, the aircraft can remain hidden up to the moment of attack and need only fear those machine guns which happen to be pointed along its flight path. In carrying out this attack the squadron would operate singly in rapid succession (so-called " chain " attack of the Italians) the formation reassembling after attack and returning on a different route. The greatest danger exists from enemy fighters attacking the formation when it is broken up. It is thus essential that the instant of attack be chosen correctly. Some war problems illustrating the author's theories are worked out in detail.

*Reconnaissance from a Great Height.* (W. Kusnjetzon, Krassnaja, Swjesda, April, 1938. Luftwehr, Vol. 6, No. 4, April, 1939, pp. 145-6.) (68/4 U.S.S.R.)

Experience in Spain and China has shown that reconnaissance aircraft operating at more than 16,000 feet are practically immune from fighter attack. To make full use of this fact, the aircraft must have a speed range from 100 to 300 m.p.h. and a service ceiling of 30,000 ft. If to this we add the requirement of an endurance of several hours we see that not only the design and equipment of such aircraft require considerable care but the crew is also subjected to great strain. Great attention must be paid to the health of pilot and observer and training in artificial low pressure chambers must alternate with frequent high altitude flights. A hole in the floor of the aircraft is essential for ground observation and the operation of the aerial camera must be simplified. At most one crew can only carry out two high altitude flights of 1½-2 hours per 24 hours, and it is therefore necessary that the observer be thoroughly familiar with the enemy's organisation so that no time is wasted. In many cases observation of the ground will only be possible through gaps in the clouds and this requires considerable experience. Contrary to expectation a ground haze is often transparent when looked through from a great height, but whenever possible high altitude reconnaissance should be carried out in the morning or evening. A rain storm often makes the air more transparent and in general the crew should be ready to carry out such work at the shortest notice.

*The Utilisation of Aircraft in the Spotting and Destruction of Submarines.* (Kolesnikow and Bessonow, Air Fleet News, U.S.S.R., July, 1938; Luftwehr, Vol. 6, No. 4, April, 1939, pp. 146-151.) (68/5 U.S.S.R.)

Under favourable conditions (sunlight, absence of wind, deep water) the maximum depth at which a submarine can be seen from an aircraft operating at 100 to 600 m. is about 15 m. This maximum depth corresponds to the case when the

submarine is approximately vertically below the aircraft (sighting angle up to 20°). With a more oblique view this depth rapidly diminishes (5 m. at 60°). If the submarine is at the surface when spotted by the aircraft, and then dives, it is possible to calculate the conical surface on which the submarine must be situated, if its rate of submergence and under water speed is known. If at the same time the distance of the aircraft from the submarine when submersion started, is known, the dimension of the circular locus on the immersion cone when the aircraft passes the original position (disturbed water!) can be determined, and the bomb dropping adjusted accordingly. As an alternative, the aircraft describes a curve round the submarine, so as to maintain a constant sighting angle, and summons other aircraft or surface vessels in the neighbourhood to participate in the hunt. The author also gives some details of how to carry out a systematic search for suspected submarines over a given stretch of water, and the minimum number of aircraft required.

*Lighting System for Air Raid Precautions.* (Engineering, Vol. 147, No. 3827, 26th May, 1939, p. 620.) (68/6 Great Britain.)

The system involves two components—a sodium source fitted with an enveloping filter and a lacquer in the complementary colour of the emitted light, which is sprayed on to the windows, roof lights, etc. The lamp and filter produce a narrow band of monochromatic yellow light to which the lacquer is opaque, and it is claimed that their combined use does not allow any visible radiation to penetrate into the outside atmosphere. The lacquer is sprayed on to the outside of the glass, forming a matt surface which prevents light from outside sources being reflected on it, and yet allows sufficient daylight (10 per cent.) to pass for general machine work and assembly processes to be carried out on a normal day without recourse to artificial lighting.

*Japanese Attacks on Chinese Aerodromes.* (Faysulin, Krassnaja Swjesda, 6/1/39; Luftwehr, Vol. 6, No. 4, April, 1939, p. 153.) (68/7 U.S.S.R.)

The main attack is preceded by a surprise reconnaissance, the route adopted missing the larger centres of population, final course being only set in close proximity to the objective. The major part of the flight is carried out at great altitudes (5,000 m.) with descent to 3,000 m. at the target. The first part of the return journey is carried out at high speed into the direction of the sun. No bombs are dropped during this reconnaissance, which is carried out by single aircraft. The main attack is carried out subsequently, after the target has been carefully studied. The Chinese, on the other hand, seem to rely on staff information when planning their operations and thus combine reconnaissance and attack in one operation.

*Russian Experiments with Under-Water Wings for Ship propulsion.* (A. N. Vladimirov, Soudostroienie, No. 7, 1938. Eng. Absts., Vol. 2, No. 3, Sect. 3, April, 1939, pp. 59-60.) (68/8 U.S.S.R.)

The stability of the horizontal motion of submerged wings and the effect of these on the propellers, are discussed. The author's conclusions indicate the complexity and difficulties of the problem of motion on the surface of the water by means of submerged wings. The greatest obstacle to a satisfactory solution of this problem is presented by cavitation, and it is considered that this will limit the possibility of utilising submerged wings for gliding boats to speeds of from 55 to 60 miles an hour. Above these speeds it is probable that the usual type of hydroplane will prove more efficient. The article contains a number of formulæ and equations and gives graphs and tables of values in connection with the various points discussed in it, and there are also a number of diagrams and illustrations of various types and sections of submerged wings.

*Reduction of Skin Friction on a Flat Plate Through Boundary Layer Control.* (J. R. Weske, J. Aeron. Sci., Vol. 6, No. 7, May, 1939, pp. 289-291.) (68/9 U.S.A.)

The author carried out approximately two dimensional tests on the friction drag of a flat plate, air being emitted at low speeds from a slot placed near the leading edge, the original direction of the jet being at right angles to the tunnel wind. The nose part containing the slot could be supported separately, the following factors being measured:—

1. Aerodynamic force produced by the discharge slot due to air emission.
2. Effect of air jet on drag of plate placed in the wake of the jet.
3. Rate of disintegration of the surface of discontinuity between jet and free air stream.

Three series of test were carried out.

*a*. Nose slot fixed and plate on drag balance.
*b*. Plate fixed and nose slot on drag balance.
*c*. Both slot and plate on drag balance (combined drag).

The wind speed in the tunnel ranged from 40 to 90 feet/sec.

From the tests it appears that, disregarding the problem of the intake, for one h.p. spent at the slot in producing the jet, 1.3 h.p. are saved through decrease of skin friction of the flat plate and through negative drag of the slot.

*Effect of Shock Waves.* (N.A.C.A. Trade Conference.) (J. Aeron. Sci., Vol. 6, No. 7, May, 1939, p. 300.) (68/10 U.S.A.)

Investigation regarding the effects of shock waves at various points on a high-speed aeroplane have been carried out in the 8ft. 500 m.p.h. wind tunnel. These shock waves around local protuberances have been observed at flight speeds as low as 300 m.p.h.

With the usual blunt-nose N.A.C.A. cowling, for example, an aeroplane speed of 325 m.p.h. causes local flow speeds at the front curve of the cowling exceeding 710 m.p.h. This design of cowling is a very poor streamline form at 400 m.p.h., though an excellent one at 250. A new design of N.A.C.A. cowling delays the onset of shock waves and thus overcomes the difficulty.

New forms of windshields and propellers developed in these investigations to avoid the onset of shock waves are also discussed. With these new forms it will be possible to achieve top speeds in level flight exceeding 500 m.p.h. without the occurrence of the drag creating compression shock.

*The Necessary Time and Fatigue Strength of Aircraft Wing Structure.* (H. W. Kaul, Year Book of German Aeronautical Research, 1938, Vol. 1, pp. 274-288.) (68/11 Germany.)

Till relatively recent times, aircraft structures were designed to fulfil certain static strength requirements and the strength specifications of leading aeronautical countries showed general agreement. It is true that certain parts, such as wing roots and control surfaces were also designed to take into account fatigue limits, but this factor was not applied to the wing structure as a whole. In addition to fatigue strength, *i.e.*, the capacity to withstand a large number of load reversals, the aircraft wing structure may be subject to occasional overloads, especially in gusty air. It is obviously impracticable to design the wings so as to withstand such loads indefinitely, but a certain margin of safety must nevertheless be maintained. The measures adopted will obviously depend on the magnitude and frequency of the loads during the life of the aircraft and will vary with type of machine, purpose of employment and atmospheric conditions (gustiness). The author has subjected to statistical analysis a large number of data covering the wing stressing of six different civil aircraft ranging in weight from 2,000 to

6,000 kg. At the same time the stress-frequency of application curves for three acrobatic aircraft were investigated. It is thus possible to state the probable number of times loads of a given magnitude will be applied to the wing structure over flying times ranging from 2,000-6,000 hrs. (life of aircraft depending on class) and the ground tests adjusted accordingly.

*Aerodynamic Principles of Automatic Stabilisers.* (F. Haus, Proc. Lilienthal Society, Oct., 1938, pp. 273-306. In course of translation.) (68/12 Germany.)

The object of the author is to show how far the classical theory of dynamic stability is of help in the special problems connected with stabilising appliances on aircraft. After showing how the general motion of an aircraft in space can be defined by nine variables, the author gives the results of flight tests during which these variables are recorded simultaneously, special attention being given to the recovery of the aircraft after having been subjected to a series of well-defined disturbances.

The object of the stabiliser is to improve this recovery. It is a mistake to attempt complete and instantaneous suppression of all variables, whatever the initial disturbance. The correct way is to destroy as quickly as possible only the most objectionable disturbances, leaving the others to be damped out naturally as a consequence of the motion of the aircraft. An aircraft flying at small incidence can always be made dynamically stable by suitable design. The trajectory of such an aircraft will, however, still possess certain objectionable features such as insufficient damping of the slow longitudinal oscillation and slow recovery from a lateral inclination. In addition there is always absence of course stability. The author concludes by showing how these defects can be remedied by the use of rationally designed stabilisers.

*The Landing of Aeroplanes on Ice.* (K. A. Moskatov, Air Fleet News, U.S.S.R., Vol. 21, No. 12, December, 1938, pp. 40-46.) (68/13 U.S.S.R.)

In the present paper a first approach is made towards the problem of landing of aeroplanes on ice, a review being given of the characteristics of ice and ice-covered aerodromes.

All the literature and research work, both Russian and foreign, has dealt with the problem of the quality, structure and strength of the ice, only fresh and artificial ice being investigated; very little work has been done on ice formed under natural conditions.

There has not so far been a single comparative investigation of the behaviour of the ice when landing an aeroplane on skis and on wheels on river—and sea—ice at different latitudes, *e.g.*, on the Baltic Sea and the Black Sea.

No accurate data is available for the variation in strength of ice according to the surrounding conditions in which it is formed and in relation to its salt content.

Individual observations made during voyages of ice breakers and other vessels in the Polar regions have shown that there are a number of other factors affecting ice formation and strength which will necessitate the working out of new coefficients. This applies to all the other ocean basins of the U.S.S.R.

*Theory of Automatic Control of Aeroplanes.* (H. K. Weiss, N.A.C.A. Tech. Note No. 700, April, 1939.) (68/14 U.S.A.)

Methods of automatically controlling the aeroplane are reviewed. Equations for the controlled motion including inertia effects of the control are developed and methods of investigating the stability of the resulting fifth and higher order equations are presented. The equations for longitudinal and lateral motion with both ideal and non-ideal controls are developed in dimensionless form in terms of control parameters based on simple dynamic tests of the isolated control unit.

*Wind Tunnel Tests of Several Forms of Fixed Wing Slot in Combination with a Slotted Flap on an N.A.C.A. 23012 Aerofoil.* (M. J. Bamber, N.A.C.A. Tech. Note No. 702, April, 1939.) (68/15 U.S.A.)

Several forms of fixed wing slot in a large-chord N.A.C.A. 23012 aerofoil were tested in the closed-throat 7 by 10ft. wind tunnel. The aerofoil extended completely across the test section so that two-dimensional flow was approximated. The model was fitted with a full-span slotted flap having a chord 25.66 per cent. of the aerofoil chord. The slots extended over the entire wing span. The wing-slot location was varied along the chord and several variations of slot gap and width were tested at each location.

The data are presented in the form of tables of important aerodynamic characteristics for each slot tested and as curves of section lift, profile-drag, and pitching-moment coefficients. The relative air velocity through the slot is given.

A slot as far back on the aerofoil as the 55 per cent. chord point, with the flap deflected 40°, was practically ineffective for increasing either the maximum lift coefficient or the angle of attack for maximum lift. A slot near the leading edge of the aerofoil, with the flap deflected 0°, increased the maximum lift coefficient by 0.65, the maximum angle of attack by 11°, and the minimum profile-drag coefficient by 0.012. With the flap deflected 40°, this nose slot increased the maximum lift coefficient by 0.40 and the maximum angle of attack by 10°.

*Tests of an N.A.C.A. 23012 Aerofoil with a Slotted Deflector Flap.* (R. O. House, N.A.C.A. Tech. Note No. 699, April, 1939.) (68/16 U.S.A.)

Section aerodynamic characteristics of a large-chord N.A.C.A. 23012 aerofoil with a slotted deflector flap were obtained in the N.A.C.A. 7 by 10ft. wind tunnel. The characteristics of an N.A.C.A. slotted flap and of a simple split flap are included for comparison.

The slotted deflector flap was found to have a somewhat lower maximum lift coefficient and somewhat higher drag at high lift coefficients than the N.A.C.A. slotted flap. At moderate lift coefficients, however, the drag of the slotted deflector flap was about the same as that of the N.A.C.A. slotted flap. The high drag of the open slot with the deflector flap neutral indicates that the slot should be closed for this condition.

*Wind Tunnel Investigation of Ground Effect on Wings with Flaps.* (I. G. Recant, N.A.C.A. Tech. Note No. 705, May, 1939.) (68/17 U.S.A.)

An investigation was conducted in the N.A.C.A. 7 by 10ft. wind tunnel to determine the effect of ground proximity on the aerodynamic characteristics of wings equipped with high-lift devices. A rectangular and a tapered wing were tested without flaps, with a split flap, and with a slotted flap. The ground was represented by a flat plate, completely spanning the tunnel and extending a considerable distance ahead and back of the model. The position of the plate was varied from one-half to three chord lengths below the wing.

The results are presented in the form of curves of absolute coefficients, showing the effect of the ground on lift, drag, and pitching moment. An appendix gives equations for calculating tunnel-wall corrections to be applied to ground effect tests conducted in rectangular tunnels when a plate is used to represent the ground.

The tests indicated that the ground effect on wings with flaps is a marked decrease in drag, a decrease in diving moment, and a substantial reduction in maximum lift.

*Aircraft Accidents and Casualties in the U.S.A. for the Period* 1928-1937. (Aeroplane, Vol. 56, No. 1462, 31/5/39, p. 709.) (68/18 U.S.A.)

For the whole ten years, the causes of accidents arrange themselves in the following order of importance:—

38% Bad weather, bad terrain.
21% Pilot error.
17% Engine failure.
15% Structural failure (usually undercarriage).
4% Personal error other than pilot.
2% Handling qualities of aircraft.

The relative order of these factors does not vary very much for each of the years considered.

This seems to show that what has been gained by wireless navigational aids has been sacrificed by forcing the pilot to fly faster and more heavily loaded machines, requiring bigger and better aerodromes for landing. On the whole there has been, however, a marked improvement in safety. In 1928 the passenger miles per passenger fatality were of the order of two million. In 1937 this figure has increased to 12 million, and this is not all a result of higher speeds covering more ground between crashes.

*Wind Tunnel Investigation of Effect of Yaw on Lateral Stability Characteristics. 1. Four N.A.C.A. 23012 Wings of Various Plan Forms with and without Dihedral.* (M. J. Bamber and R. O. House, N.A.C.A. Tech. Note No. 703, 1939.) (68/19 U.S.A.)

Four N.A.C.A. 23012 wings were tested at several angles of yaw in the N.A.C.A. 7 by 10ft. wind tunnel. All the wings have rounded tips and, in plan form, one is rectangular and the others are tapered 3:1 with various amounts of sweep. Each wing was tested with two amounts of dihedral and with partial-span split flaps.

The coefficients of lift, drag, and pitching moment are given for all the models at zero yaw. The coefficients of rolling moment, yawing moment, and side force are given for the rectangular wing at all values of yaw tested. The rate of change in the coefficients with angle of yaw is given in convenient form of stability calculations.

*Water Flow Lines About the Hull of a Seaplane.* (N.A.C.A. Trade Conference.) (J. Aeron. Sci., Vol. 6, No. 7, May, 1939, p. 300.) (68/20 U.S.A.)

Investigations have been carried out in the N.A.C.A. towing tank over a period of years to determine the design factors that will allow seaplane floats of minimum resistance to be designed.

Investigations during the year have been made using a hull fitted with a glass bottom. On the under surface of the glass next to the water, long silk streamers have been placed. Illumination has been provided so that the character of the water flow over the hull can be observed from the beginning of the take-off to the point where the boat rises on the step, assumes a planing angle, and finally leaves the water. Motion pictures illustrated the character of the flow as affected by different design characteristics of the hull.

The streamers showed the details of the water flow near the hull and permitted a close study of the design factors, the correct application of which will lead to minimum resistance hulls. The above method, applied for the first time by the N.A.C.A., offers great promise for further improvements in the take-off and landing characteristics of seaplanes and flying boats.

*Use of Hydrofoils for Assisting the Take-off of Large Seaplanes.* (N.A.C.A. Trade Conference.) (J. Aeron. Sci., Vol. 6, No. 7, May, 1939, p. 300.) (68/21 U.S.A.)

Any large reduction in the air drag of conventional flying boat hulls usually results in poor performance on the water as landing and take-off gear.

A possible solution is the fitting of a special landing and take-off gear in the form of hydrofoils which will be retracted in flight and lowered for take-off and

landing. The hydrofoils are generally similar to aerofoils but run submerged in the water. They develop large lift with small resistance and when suitably arranged beneath a streamline fuselage will lift it out of the water at very low speed and at the same time produce a water resistance of around one-half that of the planing hull that they replace. Thus marked improvement in flying boats should result from the use of an almost perfectly stream-lined fuselage for low air resistance and flotation, with retractable hydrofoils for landing and taking off.

*Study of Recovery from Spin.* (N.A.C.A. Trade Conference.) (J. Aeron. Sci., Vol. 6, No. 7, May, 1939, p. 301.) (68/22 U.S.A.)

During recent years the problem of spinning has been extensively investigated in the N.A.C.A. free-spinning wind tunnel and the results correlated with flight experience on a number of aeroplanes.

As a result of these investigations the committee has developed a criterion or design standard for aeroplane tails that will assure satisfactory recovery from spins. By a simple method, described and demonstrated in the free-spinning wind tunnel a designer can readily check his design of tail surfaces and determine whether or not it will guarantee prompt recovery from a spin. The development of this criterion is another step in improving the safety of military, commercial, and privately owned aeroplanes.

*An Experimental Investigation on the Normal Acceleration of an Aeroplane Model in a Gust.* (P. Donely, N.A.C.A. Tech. Note No. 706, May, 1939.) (68/23 U.S.A.)

In order to provide experimental data as a check of the theories used in the prediction of applied loads on aeroplanes due to atmospheric gusts, an investigation was made in the N.A.C.A. gust tunnel to determine the influence of the aeroplane wing loading, the forward velocity, the wing plan form, and the fuselage on the reaction of the aeroplane to a known gust. Tests were made for four values of gust velocity and for two gust gradients, namely, the sharp-edge gust and a gust rising linearly to full strength in a distance of several chord lengths.

The results of the investigation indicate that the formulæ given in a 1937 S.A.E. paper by R. V. Rhode entitled " Gust Loads on Aeroplanes " predict the qualitative effect of gust velocity, forward velocity, wing loading, wing plan form, and gust gradient on the acceleration increment in a satisfactory manner. The quantitative agreement is also good for aeroplanes of normal proportions when the fuselage is neglected in the computations; *i.e.*, when the wing area, intercepted by the fuselage, is included as a part of the wing. Although the agreement between computed and test results remained good for aspect ratios as low as 2.0, there is an indication in Technical Note No. 682 that, in some cases, the influence of the finite span may require more careful consideration.

The investigation also shows that the value of maximum lift coefficient for steady flow does not limit the acceleration increment in a gust.

*A Simplified Method for the Calculation of Aerofoil Pressure Distribution.* (H. J. Allen, N.A.C.A. Tech. Note No. 708, May, 1939.) (68/24 U.S.A.)

A method is presented for the rapid calculation of the pressure distribution over an aerofoil section when the normal force distribution and the pressure distribution over the " base profile " (*i.e.*, the profile of the same aerofoil were the camber line straight and the resulting aerofoil at zero angle of attack) are known. This note is intended as a supplement to N.A.C.A. Reports Nos. 631 and 634, wherein methods are presented for the calculation of the normal force distribution over plain and flapped aerofoils, respectively, but not of the pressures on the individual surfaces.

Base-profile pressure-coefficient distributions for the usual N.A.C.A. family of aerofoils, which are also suitable for several other commonly employed aerofoils,

are included in tabular form. With those tabulated base-profile pressures and the computed normal force distributions, pressure distributions adequate for most engineering purposes can be obtained.

*Determination of the High Altitude Performance of Aero Engines on the Basis of Performance Measurements Made Under Ground Conditions.* (J. Zeyns and H. Caroselli, Year Book of German Aeronautical Research, 1938, Vol. 2, pp. 7-15. In course of translation.) (68/25 Germany.)

A knowledge of the altitude performance of aero-engines is becoming of increasing importance as operational heights are tending upwards. Since high altitude test benches are not generally available and are moreover expensive as well as cumbersome, numerous attempts have been made to calculate the altitude performance from ground tests by applying certain correction factors. The well-known Brooks formula utilises three factors $f_1$, $f_2$ and $f_3$. The first factor $f_1$ allows for the increase in the supercharger pressure ratio with decrease in the blower intake temperature with altitude. The factor $f_2$ gives the power increase with reduction of intake temperature whilst the last factor $f_3$ allows for the increase in power due to the exhaust back pressure being less than the induction pressure. The Brooks formula gives fair results for altitudes near the supercharged height. If the engine is operating above the supercharger height, the Brooks values are too low. Discrepancies also occur if the engine has appreciable overlap in the valve timing. The author develops new expression for the value of the factors $f_1$, $f_2$ and $f_3$ which take into account any valve overlap and applies the correction to the i.h.p. instead of the b.h.p. of the engine (i.h.p. is obtained from motoring tests at the same throttle opening). It appears from the examples (comparison of prediction and high altitude test bench results) that the new formulæ are in satisfactory agreement with experiment.

*Methods of Improving the Fuel Consumption of Four-Stroke Spark Ignition Engines.* (F. A. F. Schmidt, Year Book of German Aeronautical Research, 1938, Vol. 2, pp. 33-6. In course of translation.) (68/26 Germany.)

It is well known that the fuel economy at a given compression ratio reaches a maximum at an excess air coefficient of about $\lambda = 1.10$. By using two spark plugs, one which gives a normal single spark whilst the second produces a series of sparks, it is possible to extend the weak mixture range to $\lambda = 1.25$, provided the ignition timing is suitably advanced and the distribution characteristics of the engine favourable. Representative consumption figures are as follows:—

| | | |
|---|---|---|
| Max. power mixture | $\lambda = .90$ | 260 gm./b.h.p. hour. |
| Max. economy (normal 2 plugs) ... ... | $\lambda = 1.10$ | 220 gm./b.h.p. hour. |
| Max. economy (2 plugs, one giving a series of sparks) ... | $\lambda = 1.25$ | 210 gm./b.h.p. hour. |

The author points out the important effect on performance of scavenging the exhaust residue in the case of supercharging. By using a weak mixture with valve overlap it is possible to obtain the same power as with a richer mixture without overlap. The engine runs cooler when scavenged and the specific fuel consumption (with weak mixture) is improved.

*Investigation of the Altitude Behaviour of a Precombustion Chamber Diesel Engine.* (R. Dull, Year Book of German Aeronautical Research, 1938, Vol. 2, pp. 37-40.) (68/27 Germany.)

Experiments were carried out on the high altitude test bench of the D.V.L. on a single-cylinder water cooled precombustion chamber Diesel engine of unspecified design (compression ratio 14/1). The intake to the engine was throttled

but not cooled to altitude value, the exhaust being evacuated to maintain pressure balance across the engine. The tests were carried out both at constant excess air coefficient $\lambda$ and at constant exhaust temperature, the injection timing being advanced to give maximum power for each throttle position. As is well known, the ignition lag of a Diesel increases with decrease in density of charge and this cannot be completely corrected by an increase in the injection advance. As a result the engine runs increasingly rough (knocks) as the intake is progressively throttled and cuts out completely at a density = .36 ground level value.

Although with constant exhaust temperature (620°C.) the power does not fall off as fast as the density (the engine at .5 density still gives .6 of the ground level b.h.p.) the specific fuel consumption is increased from 210 gm. to 240 gm./b.h.p. hour over this range.

*Experiments with the Lanova Aircraft Diesel.* (K. Lohner, Year Book of German Aeronautical Research, 1938, Vol. 2, pp. 41-3.) (68/28 Germany.)

In the Lanova Diesel the fuel is injected horizontally across the main combustion chamber and enters the throat of a subsidiary combustion chamber (10-20 per cent. of the clearance volume). This chamber is only cooled indirectly and under load assumes a high temperature (600°C.).

Ignition starts in the subsidiary chamber and the resultant explosion causes a pressure difference and discharge into the main combustion chamber where the combustion is completed. Piezo-electric indicator diagrams demonstrate this function of the chamber and also show that the combustion pressure in the main cylinder seldom exceeds 50 atmospheres, whilst the ignition pressure in the chamber is above 100 atmospheres. Adapting the Lanova principle to aircraft use presents certain difficulties, since the engine is sensitive to the temperature of the subsidiary chamber and the temperature rises very markedly under supercharged conditions. Initial ignition in the main cylinder must be avoided as otherwise very harsh running results. The difficulty was overcome by adopting a form of pilot injection, *i.e.*, the main fuel is sprayed into the flame issuing from the subsidiary chamber after a prior injection of a small quantity of fuels. It is stated that this procedure also overcomes starting difficulties.

*Relative Fin Area of Some Air-Cooled Engines.* (Les Ailes, No. 934, 11/5/39, p. 7.) (68/29 France.)

| Engine. | Stroke Volume (litres) | No. of Cyl. | Take-off Power. | Fin Area/St. Head. | Fin Area/St. Cyl. | Vol. ($m^2/l$) Total. | Fin Area/ h.p. per cyl. $m^2$/h.p. |
|---|---|---|---|---|---|---|---|
| Wright Cyclone G.R. 1820 | 29.85 | 9 | 850 | .370 | .155 | .525 | .0184 |
| Wright Cyclone G. 100 ... | 29.85 | 9 | 1100 | .435 | .168 | .603 | .0164 |
| Bristol Pegasus 18 ... | 29.10 | 9 | 980 | .387 | .195 | .582 | .0172 |
| Bramo Fafnir ... ... | 26.8 | 9 | 950 | — | — | .661 | .0187 |
| B.M.W. 132 ... ... | 27.7 | 9 | 880 | — | — | .602 | .0190 |
| Napier Rapier ... ... | 8.86 | 16 | 340 | .272 | .203 | .475 | .0123 |
| Argus As 410 ... ... | 12.0 | 12 | 450 | .389 | .264 | .653 | .0175 |

*Intermittent Flow Coefficients of a Poppet Valve.* (C. D. Waldron, N.A.C.A. Tech. Note No. 701, April, 1939.) (68/30 U.S.A.)

Flow coefficients were determined for the inlet valve of a modern air-cooled cylinder during operation of the valve. The cylinder head with valves was mounted on a large tank that could be evacuated. Operating the valve with a rotating cam allowed air to flow through the valve into the evacuated tank. The change of pressure in the tank was a measure of the amount of air flowing through the valve in a given number of cycles. The flow coefficients were determined from the pressure across the valve, the quantity of air flowing, and the valve-lift curve. Coefficients were measured with lifts of 0.1 to 0.6 inch and speeds of 130 to 1,200 r.p.m.

Conclusions.

1. Flow coefficients measured with steady-flow conditions can be applied to intermittent-flow conditions with no correction for valve-opening speed.

2. The over-all flow coefficient of a valve with any lift curve can be accurately computed by the method described if the flow coefficients of a similar valve are known at values of lift of 0.1, 0.2, 0.3 inch, and so on.

3. When a valve seat has a well-rounded approach, flow coefficients above 1.00 can be obtained if the flow area is computed from the inside-seat diameter.

*The Combustion Gas Turbine, Its History, Development and Prospects.* (A. Meyer, Proc. Inst. Mech. Eng., May, 1939, pp. 197-212. Metropolitan-Vickers Tech. News Bull. No. 691, 19/5/39, p. 10.) (68/31 Great Britain.)

Inventors appear to have been at work on the gas turbine since 1791, the original attractions of the proposal being its simplicity and the elimination of the reciprocating motion of the early steam engines. The efficiency attainable under present conditions is 17-18 per cent., but this would be increased to 23 per cent. if the gas inlet temperature could be raised from 1,000 to 1,300°F. The proposed new fields of application of the gas turbine include locomotive and marine propulsion, blast furnace plants, and the power supply for wind tunnels. Illustrated with 18 diagrams and three photographs.

*The Study of Air Flow in an Engine Cylinder.* (D. W. Lee, N.A.C.A. Tech. Reports No. 653, 1939.) (68/32 U.S.A.)

A four-stroke-cycle test engine was equipped with a glass cylinder and the air movements within it were studied while the engine was being motored. Different types of air flow were produced by using shrouded intake valves in various arrangements and by altering the shape of the intake-air passage in the cylinder head. The air movements were made visible by mixing feathers with the entering air, and high-speed motion pictures were taken of them so that the air currents might be studied in detail and their velocities measured. Motion pictures were also taken of petrol sprays injected into the cylinder on the intake stroke.

The photographs showed that a wide variety of induced air movements could be created in the cylinder; the movements always persisted throughout the compression stroke; and the only type of movement that persisted until the end of the cycle was rotation about the cylinder axis. The velocities of the air currents were approximately proportional to the engine speed and had about the same value whether the flow was orderly or turbulent. Orderly air movements greatly aided the distribution of the sprays about the cylinder.

*Dimensional Analysis and the Performance of Centrifugal Pumps and Fans.* (J. Jennings, Engineer, Vol. 167, No. 4349, 19/5/39, pp. 614-5.) (68/33 Great Britain.)

The following are considered to be some of the advantages of dimensional analysis applied to pumps:—

1. The characteristic curves are directly comparable with one another with regard to the effect of differences of design independent of slight differences of size and speed.

2. The curves have the same scales for consistent English or metric units.

3. The effect of viscosity and roughness can be investigated independently of other variable quantities.

4. The pump and fan similarity laws are embodied in the curves and need not be considered separately.

5. The relation between experiments on models and on the operation of full-scale machines can be examined easily.

6. The operation of pumps with fluids of varying density and viscosity may be more easily forecast.

*Knock in Otto Cycle Engines.* (H. Weinhart, L.F.F., Vol. 16, No. 2, 20/2/39, pp. 74-83. Eng. Absts., Vol. 2, No. 4, Section 2, April, 1939, p. 43.) (68/34 Germany.)

The author reviews the progress of research on the " knocking " of internal-combustion engines, and the alternative theories according to which the phenomenon is due either to " pressure-ignition " in the residual charge, or to the impact on the cylinder-walls of a " detonation-wave " in the residual charge. He describes experiments carried out on a cylindrical pressure-vessel and also on an aircraft engine in which records were taken to establish whether or not the respective characteristic phenomena postulated by the rival theories occurred solely in association with " knocking." These are the formation of directionally-determined pressure waves, as determined by pressure measurements; the abrupt increase to a maximum of the electric current in the recording plugs employed in ionisation tests; and flame velocities exceeding considerably those associated with normal combustion. The pressure measurements were made by the piezo-electric method, whilst the ionisation method in conjunction with cathode-ray oscillograph recording was used to ascertain the combustion velocities.

The author concludes that the variation of the ionisation current caused by gas mixtures detonating in a pressure vessel differs fundamentally from that observed in a " knocking " motor; it can thus be asserted that in the latter no " detonation wave " is formed. He considers that, so far as the tests permit conclusions to be drawn, they indicate spontaneous ignition of the residuary charge due to its compression as the cause of the " knocking " phenomenon.

*Measurement of the Flow Velocities in the Cylinder of an Externally Driven Aircraft Engine.* (H. Wenger, L.F.F., Vol. 16, No. 2, 20/2/39, pp. 62-73. Eng. Absts., Vol. 2, No. 4, Section 2, April, 1939, p. 43.) (68/35 Germany.)

The author presents the results of researches on the flow velocities in the cylinder of an externally-driven experimental single-cylinder aircraft engine of 160 mm. (6.3in.) bore and 190 mm. (7.5in.) stroke. The tests were made at high speeds—500-1,800 r.p.m.—by the heated wire method due to J. Ulsamer (Diss. Techn. Hochschules, Munchen, 1932), which permits measurements to be made even if the velocity and the temperature vary rapidly and within wide limits during one revolution. The author discusses the principles upon which this method is based, and describes the apparatus used. The tests covered the influence upon the air velocity of the rate of revolution, the setting of the carburettor, the cooling-water temperature, and the compression-ratio. The results indicated that, generally speaking, the variation of the flow-velocity during a revolution was of uniform character. It attained a maximum during the suction phase, decreased during the compression phase, and increased again during the expansion and scavenging phases. In order to assess the influence of the rate of revolution and of the carburettor setting, the mean speeds for the various phases, as well as for the whole revolution, were determined and plotted separately.

*Vibration of Radial Aircraft Engines.* (Part I.) (G. P. Bentley, J. Aeron. Sci., Vol. 6, No. 7, May, 1939, pp. 278-83.) (68/36 U.S.A.)

A complete theoretical study of gas and inertia vibration forcing functions in 7 and 9-cylinder single row and 14 and 18-cylinder twin row radial aircraft engines with articulated connecting rods is outlined qualitatively in part I, and the results presented in mathematical terms in chart form.

In part II (to be published) engine vibration in an unrestrained engine mounting arrangement is outlined theoretically and charts provided to permit calculation of free engine vibration in all degrees of freedom. All theoretical work in parts I and II was verified by full-scale tests on two 9-cylinder and two 14-cylinder engines, operating under conditions of negligible restraint, and by full flight

vibration surveys on two aeroplane engine installations of the same freely mounted test engines. Plots are included comparing the test results with the theoretical work both on the ground and in the air.

*Dynamic Strength Characteristics of Light Alloys at Low Temperatures.* (K. Bungardt, Year Book of German Aeronautical Research, 1938, Vol. 1, pp. 529-531.) (68/37 Germany.)

Both for aluminium and magnesium alloys the fatigue strength under bending increases with decreases in temperature ($+20°C.$ to $-65°C.$).

The increase (approximately 20 per cent.) is especially marked in the case of Al-Cu-Mg alloys, Al-Mg alloy containing 4.68 per cent. Mg, and Mg-Mn alloys.

The impact strength (notch test) also increases by 15-20 per cent. with reduction in temperature from $+20°C.$ to $-65°C.$ except for an Al-Mg alloy containing 7 per cent. Mg, a Mg-Al alloy containing 7 per cent. Al, and a Mg-Mn alloy containing 2 per cent. of Mn.

For these three alloys reduction of temperature has a very slight detrimental effect.

*Slow-Ageing Light Alloys and Their Use as Riveting Materials.* (K. Matthaes, Year Book of German Aeronautical Research, 1938, Vol. 1, pp. 504-510.) (68/38 Germany.)

The duralumin rivets used up to now in aircraft construction have the following composition:—

| | |
|---|---|
| Cu | 3·7-4·7% |
| Mg | ·4-1 % |
| Sc | ·1- ·7% |
| Mn | ·3- ·7% |
| Fe + Ti | <·5% |
| Zn | <·1% |
| Al | rest. |

This material (fully hardened) has a great shear strength (27 kg/mm²) but is liable to crack, especially if high-speed riveting machines are employed. The rivets must, therefore, be used before the ageing has fully developed, *i.e.*, within 2½ hours if stored at 20° after heat treatment. This period can be appreciably lengthened by cold storage of the rivets (ice box). This method is, however, inconvenient and expensive. The Heinkel works have lately produced a new alloy for which the age hardening only begins to develop after 20 hours storage at 20°C. The final Brinell hardness of this new alloy (German pat. applied for) is 100 kg/mm² (against 120 of the original Dural rivets). The shear strength of the worked rivet is practically the same as before. The composition of the new material is as follows:—

| | |
|---|---|
| Cu ... | 2.09% |
| Mg ... | 2.09% |
| Sc ... | ·78% |
| Mn ... | ·55% |
| Fe ... | ·47% |
| Al .. | rest. |

It is stated that the corrosion resistance is satisfactory.

*Construction of Welded Structural Parts.* (W. Rethel, Year Book of German Aeronautical Research, 1938, Vol. 1, pp. 495-500.) (68/39 Germany.)

The great advantage of welding is the possibility of constructing hollow and therefore stiff parts. In the case of mass production the constituent sheet elements can be pressed, bent or cut to the requisite size with great accuracy by means of automatic tools. The parts are then assembled in formers, the only

skilled work being the final welding of the assembly. With suitable material and gas a good weld can always be obtained by a welder of average skill, provided the part is so designed that simple welds can be employed. It must be possible for the edges of the weld to warm up equally, concave corners should be avoided, and in case of large flat pieces, with welds near the edges, it is essential that an edge or groove be provided at a distance from the weld of 20 $d$ ($d$ = thickness of plate) in order to prevent buckling.

If these precautions are borne in mind, it is possible to build up structural parts which can be utilised without requiring any subsequent straightening and re-setting. Photographs show various welded aircraft components illustrating design features discussed (float fittings, wing fittings, spar joints, etc.). Of interest is a completely welded wing with 17 intermediate ribs.

*The Effect of Cu, Mg and Si Content on the Properties of Al-Cu-Mg Alloys.* (M. Hansen, Year Book of German Aeronautical Research, 1938, Vol. 1, pp. 501-3.) (68-40 Germany.)

Considerable quantities of Cu-Mg-Al alloys are utilised in the German aircraft industry and the problem arose how to save the copper consumption without diminishing the strength characteristics of the alloy.

After investigating a large number of alloys, the author concludes that the two standard aircraft alloys containing 4 per cent. Cu, 0.6 per cent. Mg and 4 per cent. Cu, 0.9 per cent. Mg respectively can be replaced by alloys containing 3 per cent. Cu, 1.5 per cent. Mg and 3.5 per cent. Cu, 1.5 per cent. Mg without any deterioration in Brinell hardness, tensile strength and yield point. In these alloys the original Mn and Si content was unaltered.

The silicon content is very important since it concerns the age hardening of the alloy at elevated temperatures. The process is very complicated since the effect depends on the quenching temperature as well as on the ageing temperature. Experiments are still in progress, but it appears that a high silicon content ($\sim$ 1 per cent.) may be beneficial.

*Cladding with Ultra Pure Aluminium (99.99 per cent.).* (P. Brenner, Year Book of German Aeronautical Research, 1938, Vol. 1, pp. 515-516.) (68/41 Germany.)

The usual material used for cladding in Germany (Specification No. 3,116) is an Al-Mg-Si alloy containing 99.5 per cent. Al.

Although this material withstands immersion in sea water for years without any ill effects, a certain amount of surface corrosion took place on aircraft. The surface attacked is very thin and there is no measurable reduction in material strength. The appearance, especially on transport machines is, however, very unsightly and the deposit may have an effect on the speed (boundary layer). Although the corrosion may be prevented by painting, this entails an appreciable increase in weight and also prevents the smooth polished surface finish so important for high speed work.

The author shows that the trouble can be completely overcome by substituting ultra pure aluminium (99.9 per cent.) for the alloy specification 3,116 utilised so far. The resultant drop in strength of the cladded article is very small and can be easily allowed for by a slightly stronger core. As this material is easily scratched, it must be protected by a hard varnish during assembly, the varnish being dissolved off on completion of the structure.

*Flush Riveting—Considerations for Quantity Production.* (D. R. Berlin and P. F. Rossmann, Aero Digest, Vol. 34, No. 5, May, 1939, pp. 54-61.) (68/42 U.S.A.)

The Curtiss-Wright Corporation initiated early in 1937 a flush riveting development project in connection with production engineering and tooling preparations

The present paper gives a summary of the basic development and the problem of tooling production. Its considerations are based on a production of 100 aircraft. The total number of rivets in the typical aircraft under consideration amount to approximately 45,000, of which 30,000 are external. For direct comparison $\frac{1}{8}$in. brazier head and flush rivets only are considered. For flush riveting, the height of the A.N. 425 rivet was reduced and special attention given to the following :—

1. The hole pior to press countersinking is drilled to size.
2. Choice of countersinking die angle.
3. Chamfering of inner edge of extrusions and formed stringers prior to press countersinking.
4. Use of a lubricant on the press countersinking punches and dies.

As a result of the investigation it is concluded that flush riveting costs approximately 30 per cent. more than present brazier riveting for all constructions of panel and fuselage riveting.

*Theory of Fatigue of Metals.* (E. Growan, Proc. Roy. Soc., Series A, Vol. 171, No. 944, 1/5/39, pp. 79-105.) (68/43 Great Britain.)

The present theory of fatigue is based upon the fact that plastic deformation is not homogeneous. The stress acting upon a plastic inhomogeneity that is embedded in elastic surroundings is a function of its plastic strain, diminishing with increasing strain. This fact, with the assumption that the plastic spot is subject to strain hardening of the usual kind, leads to the existence of safe and unsafe ranges. The derived dependence of the safe range upon the mean stress of the cycle is the same as that deduced by McAdam from empirical data. The relation between the stress range and the number of cycles after which a crack is formed, as calculated from the theory, is in accord with the typical $\log S - \log N$ curves given by experiments. Conclusions from the theory about fatigue endurance at elevated temperatures, about the correlation between fatigue endurance and strength, about mechanical hysteresis, etc., are confirmed by experience.

*The "Pack" Method for Compressive Tests of Thin Specimens of Materials Used in Thin Wall Structures.* (C. S. Aitchison and L. B. Tuckerman, N.A.C.A. Report No. 649, 1939.) (68/44 U.S.A.)

The strength of modern lightweight thin wall structures is generally limited by the strength of the compression members. An adequate design of these members requires a knowledge of the compressive stress-strain graph of the thin wall material. The "pack" method was developed to meet this case.

In the "pack" test an odd number of specimens are assembled into a relatively stable pack, like a "pack of cards." Additional lateral stability is obtained from lateral supports between the external sheet faces of the pack and outside reactions. Studies have been made of the reproducibility of the test results by testing packs taken from sheets of aluminium alloy 17 ST and steel. The largest spread in yield strength was about 2 per cent. Tests were also made to determine whether the results from packs were like those obtained from compact solid specimens. The results indicated that the method of transverse support had no appreciable effect on the yield strength. The largest difference between a pack and a solid specimen was 1.60 per cent.

*Bearing Metals for High Speed Engines.* (Foundry Trade Journal, Vol. 60, No. 1177, 9/9/39, p. 209. Eng. Absts., Vol. 2, No. 3, Sect. 3, April, 1939, pp. 67-68.) (68/45 Great Britain.)

The severe conditions under which modern internal combustion engines function has led to the development of new bearing metals as alternatives to white metal.

These new alloys are known respectively as copper-lead, cadmium base, hardened lead and silver bearing alloys. The first two of this list are chiefly used

in the U.S.A., whilst hardened lead is favoured in Germany. Copper-lead alloys are subject to fatigue cracking which can be remedied by the addition of tin. Unfortunately the resultant alloy is subject to seizure when overstressed. Cadmium base alloys (cadmium with small additions of nickel, or tin and silver) have high fatigue value but are subject to corrosion by hot oil. Hardened lead contains 1-2 per cent. of tin together with small additions of other elements (calcium, cadmium, arsenic, copper, etc.). Except for corrosion, it is superior to white metal.

Silver or silver rich alloys present the latest development for bearing metals. Whilst possessing a better seizure resistance than any of the alloys listed above, silver is difficult to bond and behaves erratically, probably due to lack of "oiliness." Attempts to overcome this difficulty by proper choice of alloy constituents or by oil "doping" are still in progress.

*Some Notes on the Numerical Solution of Shear-Lag and Mathematically Related Problems.* (P. Kuhn, N.A.C.A. Tech. Notes No. 704, 1939.) (68/46 U.S.A.)

The analysis of box beams with shear deformation of the flanges can be reduced to the solution of a differential equation. The same equation is met in other problems of stress analysis. No analytical solutions of this equation can be given for practical cases, and numerical methods of evaluation must be used. Available methods are briefly discussed. Two numerical examples show the application of the step-by-step method of integration to shear-lag problems.

*New Photo-Elastic Method for Three-Dimensional Stress Investigations.* (R. Weller, Mech. Eng., Vol. 61, No. 6, June, 1939, p. 469.) (68/47 U.S.A.)

Three dimensional photo-elastic investigations have been carried out previously by treating the plastic model at an elevated temperature and then cooling. The cold material is then sliced in any direction and investigated as in the two-dimensional case. The method obviously depends on the fact that the cold material retains the stress pattern after slicing.

In the new method, the stressed plastic model is investigated directly by a beam of light focused on any interior part. To prevent any disturbing effects at the surface of the model, the latter is immersed in an oil bath of the same optical properties.

Under these conditions the light entering the model is scattered laterally by an amount depending on the internal strain conditions and the resultant pattern is utilised for stress investigations.

The new method has the following advantages:—

(1) The model is not destroyed by mechanical cutting and can therefore be used repeatedly.
(2) Heating and cooling is no longer necessary and uncertainty of constancy of physical factors is removed.
(3) Differential fringe patterns may be observed when taking account of any initial stresses.
(4) Stress direction and principal values are obtained by rotating the model during observation and a complex analysis is not required.
(5) Intermediate check points can be obtained by loading and unloading tests.

*New Developments in the Riveting and Welding of Light Alloys.* (E. V. Rajakovics, Z. Metallk., Vol. 31, No. 5, May, 1939, pp. 137-140.) (68/48 Germany.)

The author discusses the new alloy duralumin 681 H which can be used for rivets in its fully hardened state (without previous heating and ice storage). This material, moreover, possesses a greater shear strength due to the cold

working (10 per cent.) after riveting, whilst the standard rivet (Dural 681 A) deteriorates slightly (4 per cent.).

Since the new material requires no previous heat treatment it is specially suited for explosive rivets.

Special reference is made to the Weibel system of electric welding for thin light metal sheets (0.2 to 1.5 mm. thick).

The welding tool consists of two carbon electrodes placed at an acute angle embracing the butt joint of the plate. Alternating current at 6 v. is used and thus no arc is formed.

The process gives excellent results for wrought Al alloys (such as dural), but suffers from the fact that the carbon electrodes burn away rather rapidly.

It is hoped to overcome this difficulty by proper choice of electrode material.

*On the Rib Stiffness Required for Box Beams.* (E. E. Lundquist, J. Aeron. Sci., Vol. 6, No. 7, May, 1939, pp. 269-77.) (68/49 U.S.A.)

In the design of stressed skin wings, it is common practice to assume that the shear webs and ribs are equivalent to rigid supports. As an idealised example of this problem the flat compression flange of a symmetrical box beam is regarded as a plate supported by transverse ribs and subjected to edge compression. A general theory for the stiffness required of the ribs to be equivalent to rigid supports is given. In addition, an approximate theory and a conservative theory for the rib stiffness are also given. The greater part of the paper is devoted to a design problem which shows in detail how to apply each theory.

*A Method of Determining End Fixity.* (W L. Howland, J. Aeron. Sci., Vol. 6, No. 7, May, 1939, pp. 284-8.) (68/50 U.S.A.)

One of the important factors in the design of a compression member is its end fixity, since, as long as the slenderness ratio of a member is reasonably large, the load-carrying ability of the member is directly proportional to its end fixity. It is unfortunate that the few cases in which the end fixity is definitely known (theoretically) seldom occur in practice. The commonly known theoretical cases are: Pin-ended columns where the end fixity coefficient is 1.0, built-in ends where the end fixity is 4.0, and the case of one fixed end and the other pin-ended which has an end fixity of 2.04. These three cases never actually occur in practice, since in pin-ended columns there is always some friction present, and built-in ends are not infinitely rigid. In a few cases of elastically built-in columns, the end fixity can be calculated theoretically, but in general the designer of an aeroplane does not know the conditions of the ends of his members accurately enough to be able to use these means. Until the present time the designer has had to estimate the end fixity of various panels or columns because he could not take into account the effect of clips, eccentric loading, flexibility of ribs, bulkheads, or edge restraints.

It is the object of this paper to present a method whereby the actual end fixity of a member on an aeroplane or in a test assembly can be determined experimentally without failing the member.

*A Semi-Graphical Method for Analysing Strains Measured on Three or Four Gauge Lines Intersecting at 45°.* (H. N. Hill, N.A.C.A. Tech. Note No. 709, May, 1939.) (68/51 U.S.A.)

The determination of the state of stress at a point in a plane, from strain measurements made on intersecting gauge lines, is not an exceptionally difficult problem, the solution being based on the generally well-known bi-axial relationships between stress and strain.

The method described by the author is essentially graphical, but does require a small amount of arithmetical manipulation. To the best of the author's knowledge, this treatment constitutes an entirely new procedure for determining

stresses from strains measured on gauge lines intersecting at 45°. The method is thought to have some advantages in simplicity and directness over both of these previously mentioned.

*A Method for Indicating Speeds of Rotation.* (G. Morris and R. S. Silver, J. Sci. Inst., Vol. 16, No. 5, May, 1939, pp. 149-50.) (68/52 Great Britain.)

A method of indicating speed of rotation is described in which the frequency of the current generated by the rotation of a small bar of iron or mild steel, attached to the rotor and in the field of an electro-magnet, is measured by a vibration galvanometer adjusted to resonance with a multiple of the required rate of revolution.

*The Utilisation of Sound Films for Harmonic Analysis.* (L. W. Pollek, Z. Instrum., Vol. 59, No. 5, May, 1939, pp. 208-210.) (68/53 Germany.)

The curve to be analysed is photographed a suitable number of times on a continuous film band, so that the area below the curve is black on the film.

The band is passed at constant speed through a normal sound reproducing camera and the variation in photo-electric E.M.F. is analysed into its harmonic constituents by means of a standard wave analyser. This consists of a super-heterodyne valve voltmeter of adjustable sensitivity responding to a single frequency lying within the range 20-16,000 periods.

The proposed method gives the amplitude of the fundamental and that of its harmonics in a simple manner, and is very useful when a large number of curves have to be investigated.

The method is so far not suitable for determining relative phase displacements.

*Portable Apparatus for the Accurate Analysis of Gaseous Fuel, Mine Gases, Gases of Combustion or Engine Exhaust Gases.* (A. Schmidt, Gluckauf, Vol. 75, 4/3/39, pp. 198-203. Eng. Absts., Vol. 2, No. 4, Sect. 4, April, 1939, p. 26.) (68/54 Germany.)

In the quantitative gas analysis by means of the apparatus described, the composition of the mixture is determined from the difference in pressure registered after ignition of the gas and absorption by a reagent. A high degree of precision is attainable as a result of certain minor factors being taken into consideration in the experimental procedure. For example, very small quantities of the absorption liquid may be used owing to the adoption of mercury as the seal for confining the gas, as well as for indicating the pressure. The necessary corrections to be made for variations of temperature during the analysis are given in a table, which indicates the influence of these variations upon the pressure. The two-standard methods of gas analysis, namely, the volumetric and the manometric systems, are compared as regards their respective accuracy, and sources of error are discussed.

*The "Maximeter."* (Retel, J. R., and Tchang-Te-Lou, Sci. et Industr. (Mecanique), Vol. 23, Jan.-Feb., 1939, pp. 47-9. Eng. Absts., Vol. 2, No. 4, Section 2, April, 1939, pp. 54-5.) (68/55 France.)

The "maximeter" is designed to record the maximum pressure occurring in the cylinder of an internal combustion engine. The indicator fixed to the engine carries a membrane, one face of which is in communication with the cylinder; to the other face a neutral gas is supplied, the pressure of which may be controlled and measured. When the pressure in the cylinder exceeds that of the neutral gas the membrane lifts and breaks an electric circuit, this inducing a secondary current which illuminates an indicating neon lamp. By varying the pressure of the neutral gas, and noting its pressure when the indicator lamp just begins to function, the maximum pressure in the cylinder can be determined with precision. The authors describe the apparatus required for a single cylinder

and for a multi-cylinder engine, and reproduce curves showing data obtained by the instrument. These indicate the possible utility of the device in experimental and routine testing and also in determining the causes of break down or inefficiency in engines.

*The Artificial Dissipation of Fog.* (D. Brunt, J. Sci. Inst., Vol. 16, No. 5, May, 1939, pp. 137-140.) (68/56 Great Britain.)

The chemical method of fog dissipation depends on removing part of the water vapour in the air by means of $CaCl_2$. The equilibrium between the vapour pressure on the surface of the suspended water drops and the surrounding air is then upset and the water drops evaporate.

The author estimates that to clear a space of 100 m. wide in a fog 100 m. deep drifting at 1 m./sec. will require about 200 litres of saturated $CaCl_2$ solution per minute, the fog being at a temperature of 5°C. At 15°C., the quantity of liquid required will be nearly doubled.

The water deposited will be highly corrosive and this together with the fact that pipe lines will have to be erected at a considerable distance from the ground (since it is not feasible to spray the liquid upwards for any distance) renders the chemical method scarcely applicable to aerodromes.

The author considers heating the fog until the water drops evaporate, a more likely solution. According to his figures, to clear a space 100 m. wide in a fog 100 m. deep drifting at 1 m./sec. will require a heat expenditure of 36 therms per minute, which is equivalent to the combustion of 20 gallons of paraffin per minute. Such a solution is clearly feasible. It should, however, be noted that neither the thermal method nor any other method yet suggested appears to offer a solution of the problems of clearing a fog in calm conditions.

*Aircraft Icing Problems.* (N.A.C.A. Trade Conference.) (J. Aeron. Sci., Vol. 6, No. 7, May, 1939, p. 301.) (68/57 U.S.A.)

The N.A.C.A. has been, for the past few years, conducting investigations on devices and systems for reducing the tendencies toward ice formation on the various parts of aircraft. These investigations are, for the most part, conducted in flight on an aeroplane especially equipped for the purpose, although some have recently been run in a special, refrigerated wind tunnel.

The aeroplane used in the icing investigations is provided with a spray apparatus mounted ahead of the part on which the de-icing system is to be investigated. By flying the aeroplane at sufficient altitude to reach freezing temperatures, icing conditions can be simulated with the spray system all the year round, and the investigation is not restricted to the winter months.

The equipment shown dealt with methods for keeping the windshield clear of ice to insure clear vision for the pilot while navigating and landing in bad weather conditions. One method consists in using two sheets of thick glass with a liquid between and an electrical heating element located in the liquid. In this way the heat is much more effectively transmitted to the outer surface of the windshield and the danger of cracking the glass by excessive local heating is avoided. Another method of providing heat is to pass air that has been heated by the engine exhaust between the two plates of glass.

*The Theory of Crystal Rectifiers.* (N. F. Mott, Proc. Roy. Soc., Series A, Vol. 171, No. 944, 1/5/39, pp. 27-38.) (68/58 Great Britain.)

The existing theories of the action of crystal rectifiers assume that between the semi-conductor and the metal there is a potential barrier which the electrons penetrate by the tunnel effect. It is shown that this theory gives rectification in the opposite direction to that observed. An alternative theory is proposed; the nature of the potential barrier is discussed and is assumed that the electrons have to be thermally excited so that they go over the barrier, instead of through it. Good agreement with experiment is observed.

*Precipitation—Static Interference on Aircraft and at Ground Stations.* (H. M. Hucke, Proc. Inst. Rad. Eng., Vol. 27, No. 5, May, 1939, pp. 301-316.) (68/59 U.S.A.)

The effect of precipitation static on aircraft reception is described and a history of previous work on the subject given. The results of an expedition assembled by the United Air Lines for a study of the subject are described under a series of chapter headings. The meteorological conditions producing the static areas were explored by flights through them and the theory of their formation is discussed. Flight tests of all known types of antistatic antennas were made in bad weather areas and their effectiveness compared. A theory that the interference results from corona produced on the plane structure was developed and tested by mounting the plane on insulators and charging it to 100,000 volts with all radio equipment and personnel on board. A method for reducing the corona was developed as a result and proved by flight tests. A study of the electro-magnetic radiation from corona discharges was made with a synthetic static generator and the operation of the metallically shielded anti-static loop antennas explained and its limitations established. A commercial form of plane discharge system was developed and its advantages and limitations are described. The application of the aircraft results to ground radio reception is discussed.

*Heavy Current Installation of the Airship "Graf Zeppelin."* (E. Hilligardt, Siemens Zeitschrift, April, 1939, pp. 172-7. Metropolitan Vickers Tech. News Bulletin, No. 662, 26/5/39, p. 6.) (68/60 Germany.)

The author points out that a feature of the supply is that it consists entirely of three-phase current, and indicates the advantages of this system, *e.g.*, freedom from radio disturbances, simpler design of motors with squirrel-cage rotors, saving in weight of 18 per cent. as compared with d.c. Current is generated by two Diesel electric generating sets (four-cylinder Diesel engine coupled to a 22 k.v.a. 220 v. 50-cycle three-phase generator). Details are also given concerning the exciter, emergency lighting, electrically operated pumps and the electrically operated rudder equipment. Illustrated with eight photographs and three diagrams.

## LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the supply of copies of translations mentioned below should be addressed to the Under-Secretary of State (R.T.P.), Berkeley Square House, W.1, and will be supplied, free of all charge, as far as availability of stocks permit. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

### AERODYNAMICS AND HYDRODYNAMICS.

| TRANSLATION NUMBER AND AUTHOR. | | TITLE AND JOURNAL. |
|---|---|---|
| 889 Zemsky, B. M. | ... | *The Hydromechanics of High Speeds.* (Trans. Joukowsky Academy of Military Aeronautics, No. 11, 1935, pp. 5-23.) |
| 891 Fediaevsky, K. | ... | *The Turbulent Boundary Layer of an Aerofoil. Part II—The Resistance Law.* (Trans. C.A.H.I., No. 316, Moscow, 1937.) |

### AIRCRAFT AND ACCESSORIES.

| | | |
|---|---|---|
| 892 Kaul, H. W.... Lindemann, H. | ... ... | *Flight Tests and Calculations to Determine the Air Forces on an Aeroplane when the Elevator is Moved.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 194-205.) |
| 894 Baumhauer, A. G. von | | *Investigations on the Safety of the Take-off of Aeroplanes in Connection with the Qualities of the Aeroplane.* (Report of Commission for the Investigation of Aircraft Material, Amsterdam, 7th November, 1938.) |
| 896 Gorsky, W. P. | ... | *Experiments with Landing Flaps.* (C.A.H.I., Tech. Note, No. 168, 1938 (Moscow).) |
| 899 Glass, F. G. ... | ... | *Choice of a Rational Design and Suitable Aerodynamic Elements for High Speed Aircraft.* (Transactions of the All-Union Conference on High Speed Aircraft, Moscow, 1936, pp. 25-52.) |
| 900 Bartsch, E. ... | ... | *Turning and Rolling Oscillations of an Aeroplane.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 233-48.) |
| 901 Betz, A. ... | ... | *Physical Limits to the Static Thrust of a Propeller.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 348-51.) |

### THEORY OF WARFARE.

| | | |
|---|---|---|
| 888 Ermakov, P. ... | ... | *Fighting Formation for Bombers while on the Route.* (Air Fleet News, U.S.S.R., Vol. 20, No. 4, April, 1938, pp. 50-3.) |
| 893 Afanasev, V. | ... | *The Rear Organisation of the Air Force in the Light of New Requirements.* (Air Fleet News, U.S.S.R., Vol. 20, No. 4, April, 1939, pp. 38-40.) |

| TRANSLATION NUMBER AND AUTHOR. | | TITLE AND JOURNAL. |
|---|---|---|
| 895 | Tempelhoff, D. von... | *Progress in the Technology of Gas Warfare Since the World War.* (Z.G.S.S., Vol. 34, No. 1, January, 1939, pp. 23-6.) |
| | | STRUCTURES AND ELASTICITY. |
| 890 | Hiltscher, R. ... | *Photo-Elastic Investigation of a Three-Dimensional Stress System Using Convergent Light.* (Forschung, Vol. 9, No. 2, March-April, 1938, pp. 91-103.) |
| 897 | Ebner, H. ... ... Koller, H. ... ... | *Transposition of the Forces in Multi-Spar Wing Structures on Failure of a Single Structural Part.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 1, pp. 452-6.) |
| 898 | Ebner, H. ... ... Koller, H. ... ... | *On the Force Distribution in Longitudinally and Laterally Braced Panels.* (Luftfahrtforschung, Vol. 15, Nos. 10-11, 10/10/38, pp. 527-42.) |
| 903 | Limpert, G. ... ... | *The Buckling of Two-Dimensional Tension Field Supports.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 427-32.) |
| | | INSTRUMENTS. |
| 904 | Grunherr, F. von ... Klotter, K. ... ... | *Faulty Readings of Aircraft Board Instruments Due to Vibration.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 3, pp. 3-5.) |
| 905 | Schmid, E. ... ... | *The Physical Pendulum of Large Period of Vibration During Looping.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 3, pp. 6-7.) |
| 906 | Schmid, E. ... ... | *Notes on the Pendulum of 84 Minutes Vibration Period.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 3, pp. 8-9.) |
| | | ENGINES AND ACCESSORIES. |
| X102 | Lurenbaum, K. ... | *Practical Investigations on Torsional Oscillations in Aero Engines.* (D.V.L. Year Book, 1932.) |
| 902 | Friedrichs, W. ... | *Air Cooling of the Charge Delivered by a Supercharger.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 2, 1938, pp. 311-4.) |

## REVIEWS.

### Rapid Navigation Tables.

By W. Myerscough and W. Hamilton. 10/6. Pitman. 1939.

In recent years there has been a serious attempt to simplify the calculations necessary for obtaining an astronomical position line in air navigation. Several tables have been published for obtaining the calculated altitude and azimuth. Many of these methods required considerable time, and were hardly shorter than the standard natural haversine formula.

Myerscough and Hamilton have shortened the calculations by one step, and their method is definitely quicker than other methods based on an "assumed position."

Altitude is correct to within $\frac{1}{2}'$ of arc and azimuth to within $\frac{1}{4}^\circ$ of the values obtainable by spherical trigonometry. This accuracy is ample for air navigation.

This useful book also contains refraction and ex-meridian tables. It finishes with convergency and dip corrections and a departure table for use with the plotter provided.

Anyone who is interested in the progress of celestial navigation is advised to familiarise himself with Myerscough and Hamilton's method, for it represents the latest advance in the simplified calculation of astronomical position lines.

### A Primer of the Internal Combustion Engine.

By H. E. Wimperis, C.B., C.B.E., M.A. Published by Constable and Co., Ltd. Price 5/-. (5th Edition.)

This book, originally written by Mr. Wimperis in 1912 has been revised by Mr. W. J. Stern, B.Sc. It is a type of book which ought to be encouraged. Usually, when a young member of the community desires to know something about an appliance such as an internal combustion engine he is faced with two alternatives, either to obtain a boy's book on the subject, which is often written by an author who does not really understand his subject, or to purchase an expensive advanced text book, which he cannot afford and would not be able to understand. This book should fulfil admirably what is wanted. The subject is introduced historically and treated in sufficient detail for the purpose, and the small amount of mathematics introduced should be capable of being understood by most people. Both Mr. Wimperis and Mr. Stern know their subject well enough to explain it clearly and well. I have only one query. I can readily understand that the gunpowder engine, described on page 2, was unsuccessful, but I am rather surprised that it worked at all, in the form illustrated, and I fancy many readers of the book will be equally puzzled.

### The Air Annual of the British Empire, 1939.

Edited by Squadron Leader C. G. Burge. Published by Sir Isaac Pitman and Sons, Ltd. Price 21/-.

This is the latest edition of this well-known annual and it is, perhaps, sufficient to say about it that it is fully up to the standard set by the previous editions.

It is always an interesting work, for it deals solely with British aviation, not only aircraft themselves, but there is an important section which describes accessories. Apart from these, there are sections devoted to such things as aerodrome equipment, engines, materials, photography, and there are also articles which discuss progress in the various fields.

As in all other countries, the low wing monoplane is still the principal feature of aeroplane design in the British Empire, though there are a few cases of the mid-wing and high wing arrangement. Biplane types are almost obsolete, though machines with this wing arrangement are still being built for training. It is an interesting speculation to consider how long this trend is likely to continue. Convenient as it is in many respects, the low wing position is about the worst possible from a pure aerodynamical standpoint, though its deficiencies may be disguised by careful fairing. One of the newer Vickers designs is a mid-wing type in which the stress is carried across the fuselage by a specially designed frame which permits easy communication throughout the fuselage. This scheme obviates the chief difficulty with this type of wing arrangement where, normally, the wing spars cross the fuselage, blocking the interior almost completely. It is, perhaps, not unreasonable to expect that this feature of design may be extensively used in the future, as it seems to have several advantages.

Generally, progress in British aviation continues along the normal direction, judging from the information in this book. There is little to record that is really novel. The sleeve valve engine continues its progress in the hands of the Bristol Co., and it seems that the older type of poppet valve is now faced with a serious rival. The fight between them will be worth watching during the next few years, and, in spite of the assistance the poppet valve receives from the designing skill of the technicians associated with it and the progress of metallurgy; I would still support the sleeve valve to win eventually, for skill and progress are not all on one side.

MAGNESIUM, MAGNESITE AND DOLOMITE.

By J. Lumsden, B.Sc. Imperial Institute, South Kensington, S.W.7. 126 pp. 2/6 net, postage 4d.

The monograph under review deals with magnesium, magnesite and dolomite. It covers all aspects of the magnesium metal industry and the other industries in which magnesite and dolomite play an important part, and reviews the world resources of magnesium minerals of economic importance, particularly magnesite. In addition to descriptions of the deposits, chemical analyses and tables of production and trade statistics are included where possible. The monograph concludes with a selected list of references to technical literature.

Magnesium metal now occupies a position of great importance in the light metals industry. Processes developed during the past few years have led to a greatly increased output, present world production being, it is estimated, in the region of 25,000 tons, most of which is employed in the light metals industry. Apart from its use in alloys, the most important modern use of magnesium is as a scavenger in metal refining on account of its strong chemical affinity for oxygen and nitrogen.

The monograph also includes sections on dolomite and naturally occurring magnesium salts, the uses for which these are particularly adapted being described.

Among Empire resources of magnesite there are extensive deposits in India, while the mineral is worked to a less extent in the Union of South Africa and Australia. Canada possesses large reserves of magnesitic dolomite. The principal foreign deposits are located in Germany (Austria), Greece, the United States, the U.S.S.R. and Manchuria. Dolomite, which, in addition to its other uses has recently been employed for the manufacture of magnesium metal, is of widespread occurrence and the United Kingdom is well supplied with domestic reserves.

Nearly twenty pages are devoted to a most valuable series of references to technical literature, both in the British Empire and abroad. It is a monograph which should be on the shelves of everyone interested in the development of magnesium.

" Magnesium, Magnesite and Dolomite " should prove of considerable value to those specially interested in light metals or refractories, and the general reader will find in it much of interest regarding the development of magnesium as a raw material of industry.

APPLIED AERODYNAMICS.

By Leonard Bairstow, F.R.S., D.Sc. Published by Longmans, Green and Co. Price 63/-.

This is the second edition of this work, which originally appeared in 1919. The first edition has been hopelessly out of date for some years, and this new edition is very welcome.

Professor Bairstow very sensibly plunges directly into his subject. In Chapter II, in which the book proper may be said to start, the first illustration is a line drawing of a modern four-engined passenger aeroplane, and the description of it is slight but adequate. Nowadays, everybody can be reasonably expected to know what an aeroplane looks like.

While there is a great deal of interest to the aeroplane designer, it is obvious that his desire for useful information has not dominated the book, for there is also much theoretical matter which at present is principally of interest to the student. This material illustrates excellently the way in which the difficulties of the subject are being slowly mastered by the mathematicians, and it would seem that when these more recent developments have reached a stage when they will be generally useful in practical design, the mathematical equipment of the designer must be increased if he is to make full use of them. This may cause difficulties, as few men are capable of being first class mathematicians, and something else as well.

The general impression one gets in reading through the book is that Professor Bairstow must be an extremely good teacher. He seems to know exactly the difficulties that the student will meet with in trying to understand what must always be a difficult subject. To take one case, I know of no book in which Joukowsky's transformation has been explained so clearly, and the simple geometrical diagrams which elucidate it are excellent. There is also a simple drafting device which could be made by any student by which this transformation can be done mechanically.

There is also an important section devoted to the subject of aerofoil theory at supersonic speeds. As the speeds of aircraft are rapidly rising it is extremely useful to have an authoritative account of the work that has been done on this subject, and the results that have been attained, and this section will be particularly valuable in a design office. Unfortunately, in a sense, all that we know seems to indicate that, when speed is high enough, a shock wave is inevitable, and if this is the case, aircraft speeds are for ever limited. More recent theory on this subject checks very well indeed with such experiments as are available, and they both lead to the same conclusion.

Dealing with the book more particularly, the first chapter outlines the development of the subject, the second describes the principles of flight. The third discusses methods of measurement, while the fourth deals with laboratory tests. Aerial manœuvres and the equations of motion occupy the fifth chapter and the sixth is concerned with fluid motion. The others discuss the aerofoil of finite span, viscous incompressible fluid in two dimensions, turbulent motion, airscrews, prediction of performance and stability. It will be seen that the subject is very well covered.

The references throughout the work are well selected and, as in the case of the first edition, much of the value of the work depends on the skill with which the really important items of research work have been picked out and exhibited. It is clear that as a work of reference, when some difficult aeronautical problem has to be investigated, this book will be invaluable. But how long it will remain

so it is difficult to say, for the rapid output of the various aerodynamical laboratories means that books of this type must be slightly out of date, even on the publishing day. It would be worth while to consider whether it would be possible to publish an appendix, dealing with recent research, say, every twelve months.

There is one regrettable matter which must be referred to. Dr. Bairstow has succeeded in writing a chapter on the development of applied aerodynamics without the slightest reference to the work of Dr. Lanchester except, casually, in connection with a propeller theory. It is incredible that this important early work should be so completely ignored. If Dr. Bairstow is in any doubt about the view of the importance of this work which is held on the continent, I would refer him to section D of "Aerodynamical Theory," edited by W. F. Durand. This section, which is by R. Giacomelli, of Rome, devotes no less than seven pages to an application of Dr. Lanchester's work, in which such phrases occur as "remarkable physical insight." It also refers to the two great ideas conceived by him, the idea of circulation as the cause of lift, and the idea of tip vortices as the cause of induced drag. We, in this country, left the development of Dr. Lanchester's work to others. Are we also going to leave to others the praise?

La Preparazione e i Risultati Scientifici Della Spedizione Polare Dell' "Italia." (The Preparation and Scientific Results of the "Italia" Polar Expedition.)

By Umberto Nobile. Mondadori, Milan. Lire 35. 1938.

This book should dispel, once and for all, the prevalent impression that the illfated "Italia" expedition was a publicity ramp, undertaken with the object of dropping down Italian flags and singing "Giovinezza" above the North Pole. On the contrary, General Nobile went north meaning to spend the whole summer in exploration flights and ground research, and eventually to let his airship winter at Spitzbergen, so as to observe the effects of intense cold upon its structure. Provision had also been made for disembarking two or three men on each flight, if conditions allowed, to make ground observations.

Particular interest attaches to the description of the scientific instruments used. Several were specially designed, since they had to combine lightness, rapidity of manipulation, resistance to vibration, and the power to resist arctic temperatures. Nobile's frank admission of their shortcomings, and of the difficulties encountered in practical use, should prove invaluable to any subsequent explorer.

The programme comprised general exploration and survey work, meteorological observations, depth soundings, and specific research into terrestrial magnetism, gravity, atmospheric electricity and radio-activity, together with investigations of plankton and diatoms, and bacteriological research. Much valuable information was lost or destroyed when the dirigible crashed, but a great deal remains. Special credit is due to Professor Behounek, who continued his studies of atmospheric electricity while drifting on the pack-ice with little hope of rescue.

This book, which is fully illustrated with photographs and diagrams of the instruments used, is an important contribution to the study of the Arctic regions. It is fittingly dedicated to the memory of the two scientists who lost their lives on the expedition—Pontremoli, lost with the dirigible, and Malmgren, who died on the ice during a forced march to bring help for his comrades.

Code International de l'Aviation.

By Francesco Cosentini. 207 pp. Dunod, Paris. Frs. 50.

This book is an ambitious attempt to harmonise and synthetise existing air navigation laws throughout the world. The author claims that the previous edition, written in English and published in America (1933), has had considerable influence on air navigation regulations promulgated subsequently in English-

speaking countries. His most interesting introduction contains (Section VII) a series of suggestions for formulating laws, which ought to be framed and exhibited in the offices of every legislative body; and he certainly carries out his own precepts that regulations should be brief, lucid, comprehensible even to those ignorant of law, presented in an orderly sequence, and not complicated by perpetual cross references. Legislative bodies in England might note his caustic reference to the Anglo-Saxon habit of publishing lengthy regulations " in which a number of heterogeneous provisions with no special inter-connection are thrown together in regrettable confusion."

Comprehensive references and a good index add to the value of this book.

O. Leib: Aerodynamik und ihre Praktische Anwendung am Flugzeug. (Aerodynamics and its Practical Application for the Aeroplane.)

Berlin. 1938. Published by Dr. M. Matthiesen and Co. 154 pp. with 74 figs.

This book is written by a chief instructor of a German Air Force flying school at Warnemuende. If future military pilots are being nursed with such an amount of applied mathematics, aerodynamical formulæ and data, that few will be lucky to remain fit for further service flying duties.

Incorporated in the book are quaint opinions, to say the least. A warning is given as to the danger of flying with cross wind at high angles of attack, indicating that the author confuses the effect of a side slip on the lateral stability with a wind blowing crosswise to the intended ground course. Flying in strong gusts is stated to be dangerous for reasons of stability (while any hint to the effect of varying lift forces produced by flying through gusts is missing). Further, the author asserts that a certain amount of instability is desirable for most aeroplane types to obtain the manœuvrability desired, that the noise of aeroplanes flying at heights of 33,000 ft. cannot be detected, and he states that the maximum lift can be obtained by elevator action only if " the air flow within the boundary layer on the top surface of the wing is increased (' erhoeht ') and the drag is diminished in relation to the lift obtained." That a spinning top always tends to maintain its original position, and that slots in wings " stop a spin by increasing a tail-heavy moment," are only minor slips.

Of what use is the elaborate production of formulæ and diagrams, if the point is missed in the essential explanatory matter?

Modern Developments in Fluid Dynamics.

An Account of Theory and Experiment Relating to Boundary Layers, Turbulent Motion and Wakes. Composed by the Fluid Motion Panel of the Aeronautical Research Committee and others, and edited by S. Goldstein. Two Vols., Clarendon Press, 1938.

The complete disagreement between the flow of a perfect fluid predicted by mathematical physical theory and the observed flow of a viscous fluid in a multitude of technical cases of importance to engineers and physicists led to the development of a largely empirical branch of physics designated *hydraulics*, to distinguish it from the *hydrodynamics* of abstract theory. The equations of viscous fluid motion remained almost totally intractable. It should be noted that in fluid wave motion, and particularly in the phenomena of sound, the success of mathematical theory is comparable with the results of the theory of elasticity. In the past 20 years the study of viscous fluid motion has received a fresh impetus. Reynolds' advice to render fluid motion visible by indicators and to be guided by observed phenomena was neglected for two generations, but is now fully appreciated.

The two volumes under review offer a wide selection of experimental methods and results based on rendering the flow visual, and summarise the various attempts to extend at least approximate mathematical-physical analysis to the observed types of fluid motion.

The work of imposing system on the efforts of contributors with widely different outlook and equipment has been carried out by Dr. Goldstein.

Chapters I and II are chiefly a descriptive account of observed fluid motions illustrated by a series of photographs selected to form a systematic introduction. In Chapter I some results from mathematical physical theory are interjected; *e.g.*, a definition of viscosity based on simple shearing motion; a definition of instational cyclic motion round a circular cylinder and a wing; Rosenhead's demonstration that a surface of separation between streams of unequal velocity rolls up into a series of discreet eddies.

In Chapter II the reader is initiated in the same way into " Boundary Layer Theory "—a rather unhappy title for the root cause of innumerable phenomena in fluid motion, in particular of the setting up of circulation round a wing, and the production of turbulence in the wake of a moving body.

Having rendered the student familiar with the external appearance of the phenomena by these somewhat heuristic methods, Chapter III gives a concise summary of mathematical physical theory, with its precise definition of the quantities involved. The notation of vector analysis is introduced with transformation to curvilinear co-ordinates, in particular to cylindrical and polar co-ordinates. The treatment follows Love's "Elasticity," that of Lamb's " Hydrodynamics " being much less adequate.

Hamilton's operator (nabla square) is correctly defined at the bottom of p. 96 as *grad div-curl curl*, but is applied both in cylindrical and curvilinear co-ordinates as *div grad*, the additional terms appearing out of the blue.

Some soluble problems in steady flow are given at the end of Chapter III and in Chapter IV.

The motion near a rotating disc yields an interesting solution in which an expansion in ordinary series is joined up to an asymptotic expansion, the two together giving a complete solution.

The same method may be applied to a flow past a flat plate, but only the expression in ordinary series is given; the series becomes divergent and the numerical value of a parameter given to six significant figures is in error in the third digit. Step-by-step methods of solution are applied to a variety of problems, and bring out the inherent objection to Newton's proud claim that he could thus solve any differential equation. The computations become too heavy, and the computer-hours required become exorbitant in relation to the value of the particular results obtained, one at a time.

In Chapter V turbulence is brought into consideration. It is worth noting that Lamb's treatise reaches the problems of turbulence, as the outstanding difficulty, only near the end of the volume.

The disrepute of so-called classical hydrodynamics was largely due to the contrast between the very great mathematical difficulties of the 600 odd pages, and their failure even to indicate the existence of turbulent motions familiar to every engineer. The treatment of turbulence in the present volumes is really the measure of the difference between the old and the new outlook. The differential equations remain the same, but it is now fully recognised that they are intractable of solution by any conceivable labour along the old lines. It is, therefore, attempted to introduce statistical methods, having some analogy with the kinetic theory of gases.

In the simplest case we may consider flow along a circular pipe in which the time-mean flow at any point is steady, while on the mean flow is superposed a chaos of cyclic flows with zero time-mean value at any point. These cyclic flows are supposed to be distinguishable entities, and may be called " eddies," as an extension of the simpler cases where they are, in observational fact, clearly defined entities.

The success of the statistical method appears to be bound up with a satisfactory definition of these variable and transient eddies, as entities with specific properties

amenable to statical treatment. No definition yet proposed has received general acceptance.

Chapter V gives a brief summary of the conceptions introduced by Reynolds, Prandtl and others. The convection of momentum is the usual basis of the analysis developed, and gives an explanation of the apparent viscosity in time-mean measurements of velocity of flow in a pipe. Taylor has introduced the conception of isotropic vorticity, which leads to great simplifications of the coefficients of the expression for dissipation of energy. Taylor has also considered the convection of vorticity which leads to expressions of a different type.

Prandtl's assumptions require an unknown linear parameter connected with the linear scale of the eddy formation. He calls it the " mixing length " of the turbulent motion, but, himself, describes it as a mere parameter. No statistical equation yet proposed has been generally accepted as giving a true account of the phenomena, even from the statistical point of view.

Of more interest are the various methods for measuring local velocity variations by observing indicators suspended in the fluid; by hot-wire meters in one, two and three dimensions, and by exploring the flow with pitot heads.

The ultra-microscope is one of the most interesting methods, and furnishes precise visual information as to the flow in the neighbourhood of the minute particles in suspension observed.

The second volume is devoted to the account of these experimental methods, but it is impossible in a review to say more than that the experimental measurements, and the accompanying photographs of visual motion are well selected and give an admirable introduction to the practical laboratory side of the subject, on which depends practically all our real physical information about resistance.

The volumes are produced by the Clarendon Press, Oxford. The printing is very good, though hardly up to the standard of the mathematical text-books produced by the Cambridge University Press. The paper is too thick and too glazed, but will withstand wear and tear. Some of the line drawings of velocity fields are hardly worthy of the Press. The two volumes will be found on the shelves of every serious student of fluid motion.

*The 641st Lecture read before the Royal Aeronautical Society since its foundation on January 12th, 1866.*

## PROCEEDINGS.

A meeting of the Royal Aeronautical Society was held in the Lecture Hall, Institution of Mechanical Engineers, Storey's Gate, Westminster, London, S.W.1, on Thursday, January 5, 1939, when a paper on "The Use of Model Data in Aeroplane Design," by Miss F. B. Bradfield, M.A., A.F.R.Ae.S., and Mr. D. L. Ellis, B.Sc., A.R.T.C., A.F.R.Ae.S., was presented and discussed.

In the chair, Mr. A. H. R. Fedden, M.B.E., D.Sc. (Fellow and President).

The CHAIRMAN: It was quite unique in the history of the Society that a lecture should be given to the members by a lady, and the members had been looking forward to the privilege of hearing Miss Bradfield present the paper. He was deeply sorry, therefore, that Miss Bradfield had not been able to attend the meeting, as the result of indisposition.

Discussing the authors' qualifications, he said that Miss Bradfield, after a most distinguished academic career, had started her professional work in 1918; she had been engaged on aeronautical research work ever since, and her many reports were familiar to those concerned with aeronautical science. Miss Bradfield had been almost entirely engaged on wind tunnel work throughout the whole period.

Mr. Ellis, after having taken an engineering degree at Glasgow, had had some practical engineering experience there and later had been engaged in the British Thomson Houston Co.'s works at Rugby. After that he had spent some years as a Technical Officer at the National Physical Laboratory, and later had devoted some time at Farnborough to aeronautical research work. At the moment he was in charge of the Vickers tunnel at Weybridge, and he was also Secretary of the Society's local branch at Weybridge.

Thus, the experience of both authors had been most extensive.

## THE USE OF MODEL DATA IN AEROPLANE DESIGN.

By Miss F. B. BRADFIELD, M.A., A.F.R.Ae.S., and
D. L. ELLIS, B.Sc., A.R.T.C., A.F.R.Ae.S.

### 1. INTRODUCTION.

My first reaction to being asked to speak on this subject was that it is the user and not the producer of model data whose views we want to hear, and I am glad to say that Mr. Ellis has agreed to co-ordinate with me, so that I have some inside knowledge to draw on, if I venture to say what a designer does.

I wish in the main, however, to take the title in rather a different way, and to discuss in what sense model tests can be expected to give results useful to the designer.

The first and most obvious point which strikes us, is how little of the total complicated business of flight can be included in the model tests. Flight is an affair of the pilot, the weather, engine reliability, vibrations, flutter, distortions, leaks, surface conditions, stretch of control cables, dynamic effects, practically none of which appear in the model tests. The purpose of model tests is to foretell by means of simple, controllable tests that can be made both quickly and cheaply how flight behaviour will change with specific variations in design.

I wish to emphasise this point of view, because I consider the essence of good *ad hoc* model work lies in this question of simple, controlled testing. This assumes that only a few variables are considered, and that a very great deal is left out. It is therefore necessary to return at every stage to flight experience. But fortunately we have by now a considerable background of flight experience, so that model tests can be used to foretell the effect of variations from known types rather than in forecasting results *ab initio*. If this concept of the scope of model tests is accepted, I think it carries the implication that the most useful tests the research establishments can carry out for the designer are ones in which systematic variation is made on an aeroplane reasonably like his of some of the most important variables (such as nacelle or radiator position, elevator balance, etc.). The designer with a wind tunnel of his own is in rather a different position, since he will accumulate a series of model tests already correlated with flight experience by which to interpret his model tests of the latest design.

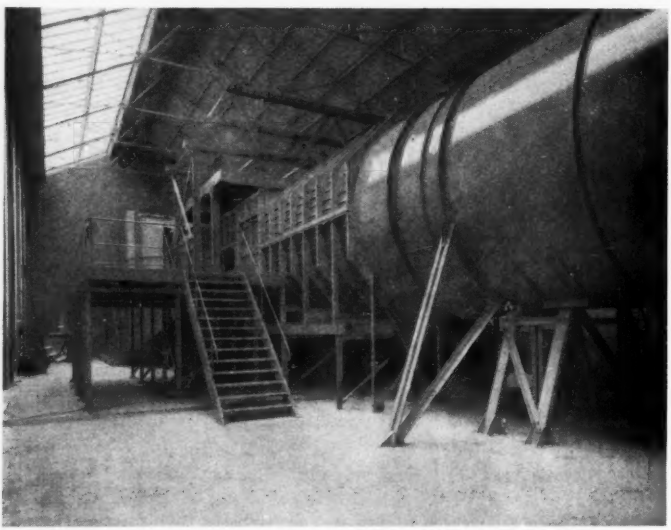

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FIG. 1.

*Wind tunnel at the Royal Aircraft Establishment.*

I have so far stressed the point that I do not expect model tests of the simple type that can be done quickly to tell the whole story, and that I regard them as primarily useful in foretelling the effect of variations from a known type. The next question is whether the model results are " right " in this restricted sense of giving the right effect for a given variation. And I will say boldly that over a wide field I do believe that model experiments can give the right answer if properly applied.

I would like in the first part of my paper to enlarge on these questions of the partial nature of model tests and of their utility if the limitations are appreciated and the results are correctly applied. In so doing I would like to consider in illustration some of the simple model tests which are made both by firms and by the official establishments, and to assume that we have at our disposal a 10ft. wind tunnel which we can run at 200 ft./sec., and that we are always pressed for time. In the second part of my paper I will then touch very briefly on how

the utility of model tests can be enlarged by the use of special apparatus (high speed tunnels, compressed air tunnels, free flight tunnels, and the like); or by more extended or more elaborate experiments than can be made in the stress of *ad hoc* work. This latter type of work will in general be possible only at research establishments.

## Part I.

### Tests which can be Made in the Designer's Tunnel.

I propose to discuss the following types of test:—

(1) Drag of an aeroplane under top speed conditions.
(2) Longitudinal stability.
(3) Cooling problems.
(4) Balancing of control surfaces.
(5) Measurement of maximum lift.

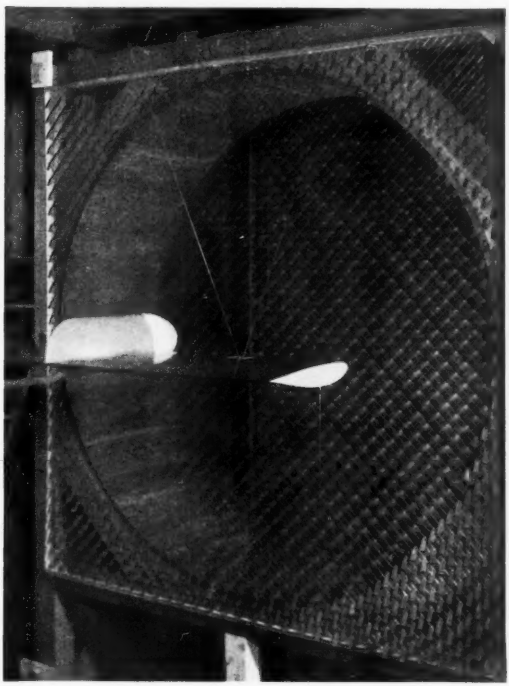

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Fig. 2.
*Turbulence screen.*

I have purposely chosen some rather difficult problems, which you may say show up the limitations rather than the utility of model work. But I have chosen them as being of practical importance and as likely to provoke discussion.

(1) Drag Measurement.

Every designer wants to know what drag his new aeroplane is going to have. The wind tunneller is given a fairly smooth, solid wooden model representing, shall we say, a twin-engined monoplane. This model is about one-eighth scale

and we can test it at rather under half its maximum speed. The turbulence, Reynolds number and model surface condition all differ from full-scale, so that we have the transition from laminar to turbulent flow occurring at different places on the model from full-scale. We might get over this by forcing the model transition points forward (by using a turbulence screen, or by tying strings round the fuselage and nacelle noses and attaching a fine wire near the leading edge of the wing). Then if we knew where the full-scale transition points were likely to be, we could calculate the change in drag consequent on this change in transition. Next we must make allowances for the scale effect on the turbulent skin friction, make individual estimates for its effect on such things as turrets, cabins, wheels, nacelles. More difficult still is the question of representing the engine or radiator drags correctly. In fact, we cannot with our 10ft. tunnel estimate the overall drag.

Let us now approach the question from another angle, and consider for a moment how we should set about estimating the full-scale drag. To begin with, there is the induced drag inseparable from the lift; under high speed conditions this is small. Next there is the turbulent skin friction of the surfaces, which can be estimated at appropriate values of the Reynolds number. In general, wing, fuselage and tail surfaces are separately estimated. This may give a value about 1.2 times the skin friction of the equivalent flat plate surface area. As deduced from flight tests, the actual value of the profile drag may be twice or two and a half times the flat plate skin friction. The object of wind tunnel tests on drag is to track down and show how to reduce this gap between $1\frac{1}{4}$ and $2\frac{1}{4}$ times skin friction.

This extra drag may arise from engine cooling, from leak systems, from high form drag of parts of the aeroplane, from interferences, or from surface roughness. Or it may arise as an extra induced drag when the distribution of circulation is bad.

I am going to discuss cooling problems in a later section, so I will pass that over at the moment, and go on to discuss leaks.

(1.1) Leaks.

The drag due to leaks can be shown in many cases to be very large (*e.g.*, 2-6lb. at 100 ft./sec. per engine nacelle represents good modern practice). Air flows in and out of the aeroplane through holes in its surface; and in this sense the cooling air is a leak system. When, however, we want the air inside the aeroplane for such a purpose as cooling and have arranged our passages to have the smallest practicable losses, we will call it a duct system, and keep the term leaks for the unwanted and undesigned flows through plate seams, cowl joints, or clearances round exhaust pipes. To get a high drag, a large flow through the leaks is necessary. If we consider whether air will flow through a particular hole, this depends on the external pressure which would obtain if the leak were smoothly sealed, on the direction in which the leak faces (*e.g.*, a pitot entry, a flush hole, a backward facing plate lap), and on the internal pressure determined by the complete leak system. Though we cannot make a model of a particular aeroplane in which its leaks are represented to scale, we can make systematic model tests on the effect of the type of leak, so that if we tabulate the size, position and type of leak on an actual aeroplane, we can from our model data estimate the drag of the leak system. The most difficult part of this estimate lies in the determination of the internal pressure, and if this can be measured in flight, the accuracy of the estimate is increased. Typical values of internal pressure are: $+0.55 \times \frac{1}{2} \rho V^2$ for a radial engine nacelle ahead of the fireproof bulkhead, $+0.08$ for a liquid-cooled engine ahead of the bulkhead, and from 0 to $-0.2$ for the general cabin space. A few typical estimates in cases in which we have 24ft. tunnel measurements of the difference in drag when leaks are sealed are added; the " calculated " values were estimated from systematic tests in the small tunnel, supplemented by measured values of the internal pressure:—

TABLE I.

DRAG, LB. FULL SCALE AT 100 FT. SEC.

| Type of Model. | Drag. Calculated. | Drag. Measured. | Quantity. cu. ft./sec. at 300 m.p.h. |
|---|---|---|---|
| (*a*) Liquid-cooled engine nacelle with nose radiator, mounted on wing ... ... | $2\frac{1}{4}$ | $2\frac{1}{2}$ | 53 |
| (*b*) Air-cooled engine nacelle ... ... | 12 | $10\frac{1}{4}$ | 229 |
| (*c*) Air-cooled engine with duct cooling ... | $5\frac{1}{4}$ | 4 | 106 |

Case (*b*) had unusually bad leaks, and is included to show that the calculation gives a result of the right order, rather than as representative of modern practice. To give some idea what these quantity figures mean, the cooling flow required to cool a 1,000 h.p. liquid-cooled engine fitted to a single-seater fighter with a top speed of 300 m.p.h. is about 250 c. ft./sec.

The model tests also show how large leak drags can be avoided if the leaks cannot be sealed. If leaks at widely differing pressures are isolated by bulkheads, the flow through them will be very much reduced. In practice this means isolating high pressure leaks (such as occur round a spinner, at wing leading edge gun holes and from the high pressure ducts of cooling systems). Alternatively, the leaks must be made to open in a backward direction, in which case they will not cause a high internal pressure even though they occur in a high pressure region (as, for example, a spinner which is made slightly larger than the body behind it).

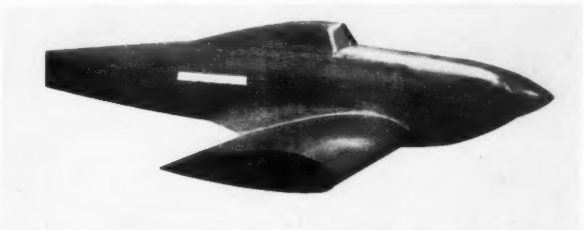

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FIG. 3.

*Partial model for cabin tests.*

(1.2) HIGH FORM DRAG.

The third way in which the actual drag of the aeroplane may be above the skin friction value arises from the fact that the aeroplane design is governed by considerations other than aerodynamic. The pilot rightly reckons good view as of the first importance, military requirements demand gun turrets with a wide field of fire; the engine designer presents us with 50-inch radial engines to be mounted on wings of 7ft. chord; the need to land on poor aerodromes leads to tyre sizes too large to enclose inside the wing or nacelle without making bulges for their reception. The tunnel can point out what in fact is being paid for the satisfaction of these requirements, and can sometimes suggest compromises. For this type of work large scale partial models are frequently the most successful. Hemispheres, wheels, strut-shaped fairings and nacelles have too much scale effect at low Reynolds number to be treated as part of a complete model. Moreover, changes in drag can be more accurately measured on partial models. It is advisable in tests of cabins, turrets, etc., to fix the transition of the fuselage (or nacelle) being tested at a forward position, as erroneous results can be obtained owing to shifts of transition due to the handling of the model during modifica-

tions. Much work has been done on partial models; I will instance tests on the drag of nacelles as influenced by the forward and vertical position of the nacelle relative to the wing, tests on unretracted and partially retracted undercarriages, tests on cabins and radiators. This question of partial model tests is straightforward if the part whose drag is being investigated does not alter the lift of the rest of the model. Suppose a length of wing is tested in a closed section tunnel, with stubs fixed to the tunnel wall continuing the wing completely across the jet. The gap between the main wing and the stubs can be kept small. In that case the overall lift coefficient measured on the balance will agree with the local lift coefficient of the wing where the nacelle is to be added, and the drag change found on adding the nacelle can be applied to the complete model at the same local value of $C_L$. This is no longer true if adding the nacelle alters the lift coefficient, because there is a local reduction in circulation, and the trailing vortex system from this will be affected by the vortex system of the aeroplane wing, and incidentally by the tunnel walls as well.

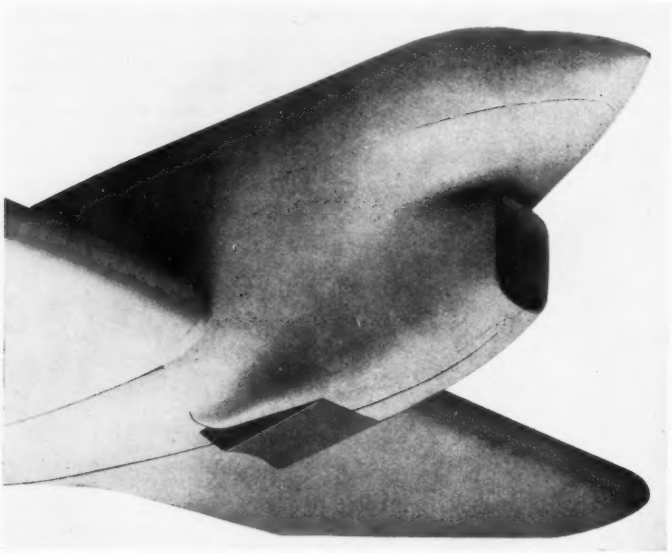

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FIG. 4.

*Partial model for radiator tests.*

You may think I am wandering into a discussion which should not affect the designer, since any corrections should be made before he sees the results. As regards tunnel correction this is certainly true, and model results should be corrected to free air conditions. But as regards the application to the particular aeroplane, this must in general be left to the designer, since such tests as these on nacelle drag are made for general application. Even if we give the results for a " typical " aeroplane instead of for a single nacelle on a wing, I am afraid the designer would invent an aeroplane which did not agree with our idea of typical.

(1.3) EXTRA INDUCED DRAG.

If a nacelle is dropped far below the wing, it causes a local reduction in circulation, which must cause an induced drag. The measured difference in drag

between central and dropped nacelles can in the main be shown to be induced drag (Fig. 5). This is important as it suggests a remedy by replacing the circulation by curling the wing trailing edge down (or extending its chord) a suitable amount. And, in fact, the major part of the drag loss can be recovered in this way. Model tests can be used to locate any local disturbances to circulation of this type and it may be possible to remove the induced drag by restoring the good distribution of circulation.

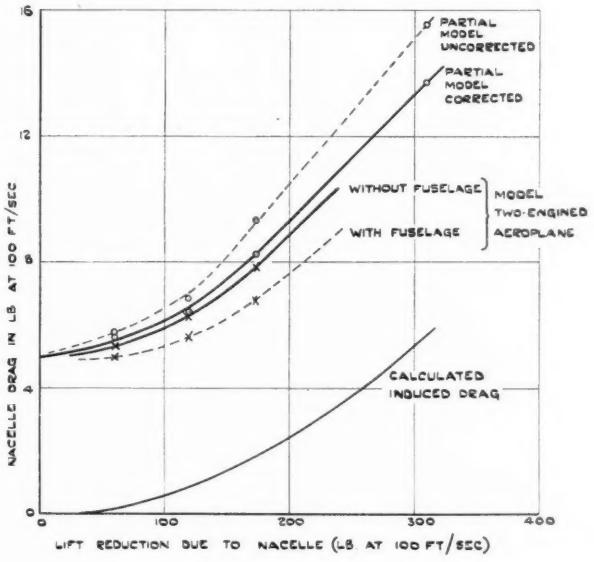



FIG. 5.

*Use of partial models for nacelle drag determination.*
*Partial model consists of one nacelle on an aspect ratio 4 length of wing.*

(1.4) INTERFERENCE.

We have still interferences to consider, and I would like to digress for a moment to suggest that this terminology of " interferences " comes from the dark ages of bits and pieces. I do not believe myself that an aeroplane which can be mentally taken apart into wings, nacelles, body, radiator, undercarriage, and so on, is a good aeroplane in general. An aeroplane is a single aerodynamic unit, and must be conceived as a whole. Let us for a moment try to analyse the aeroplane shown in Fig. 6 into " parts " and " interferences." Firstly, how do we join up the wing when we have taken the body away? If we continue the wings until they meet at an angle, this wing will have an increased drag associated with the expansion caused by the dihedral on the thick wing section. What, again, is the drag of the engine fairing as distinct from that of the radiator and undercarriage?

To my mind it is better in general to use the single conception of form drag, and to use the skin friction drag as our basis of comparison rather than the drag of each part considered separately.

Traditionally, however, we talk of interference when the body-wing junction is badly designed. Interference also occurs when such extraneous blobs as faired D.F. loops are mounted on a strut above a cabin. There is a beneficial scale

effect on wing roots, so that model tests in this case are pessimistic; but can sometimes be successfully used to suggest the kind of modification which will cure a bad full-scale design.

(1.5) Surface Roughness.

This cannot be treated in the tunnel we have so far assumed. It can be measured on the actual aeroplane in flight by the " comb " method, and the data on which the designer will settle what degree of smoothness to adopt will come from such flight tests supplemented by tests in the compressed air tunnel.

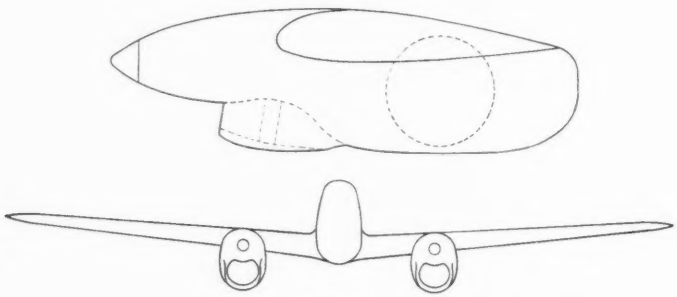


Fig. 6.

*Twin engine monoplane.*

(1.6) Airscrews.

The slipstream effect is small under top speed conditions. There remains the most important point of the effect on the airscrew efficiency of its position relative to the wing. Here the wind tunnel can give very valuable information, but the small motors required to be fitted into models are expensive, and this work seems to me more suited to a research establishment than to a designers' tunnel, and is in fact being done at the National Physical Laboratory.

I have spent a good deal of time over this question of drag, because opinion has fluctuated so widely over the years as to whether wind tunnels could give a useful answer. It seems to me an instructive case, because, in fact, our early tests did not comply with our requirement that the tests should be " controlled." We had one important variable—the transition point—hopping about without our knowledge. We have lost our early optimism that we could measure everything, but we have also lost our later pessimism that we could measure nothing correctly.

(2) Longitudinal Stability.

From one point of view, assisting the designer as regards drag reduction is a straightforward matter; at least, we all agree that it is low drag we want, and that (always assuming the engine plays fair) a given reduction in drag will make the aeroplane go an appropriate amount faster. Assisting the designer as regards longitudinal stability is not quite so simple, as what the pilot wants is in this case more complex. He probably wants an aeroplane that is light on the stick, stable when the stick is released, for preference slightly more stable as the stall is approached, which does not change either the trim or the force on the stick when the engine is throttled back or the flaps are pulled down, and which has ample elevator control for landing. All these conditions must be met over a wide C.G.

range; and it is undesirable that the pitching moment should change much with sideslip.

Any wind tunneller will know that the tests needed to cover all the points raised above cannot be made quickly or easily. Slipstream tests introduce difficulties; when $T_c$ is large (slow climb and take-off conditions) it is difficult to make tests at a reasonably high value of the Reynolds number. If motors are fitted in the models, these become expensive and slow to make. If independent drives are used the tests are prolonged, since the airscrews must be adjusted for each incidence and stand corrections be measured. An attempt is therefore being made to systematise the effect of slipstream by making a connected series of tests and deducing from these corrections applicable to any fairly similar aeroplane. This work is not complete, and I only mention it here because I think it illustrates the right way for tunnels to be used when a rather slow and expensive type of test is required. The *ad hoc* test need then only be made in exceptional cases.

Similarly, satisfying the above requirements involves knowledge of the hinge moments of elevators with various forms of balance and the behaviour of trimming tabs. These tests cannot satisfactorily be made at the Reynolds number of the complete model, and larger models of the tailplane mounted on a short stub body will be required. Again, I believe that such tests as these are best made systematically so that the designer has a series of tests from which to choose the one giving the qualities he wants. These tests on tail models have the incidence and velocity of the free stream. To apply them to the complete model, the tail incidence and mean velocity at the tail must be measured on his model. We are going to discuss the balancing of controls in a later paragraph, so I will leave further comments until then.

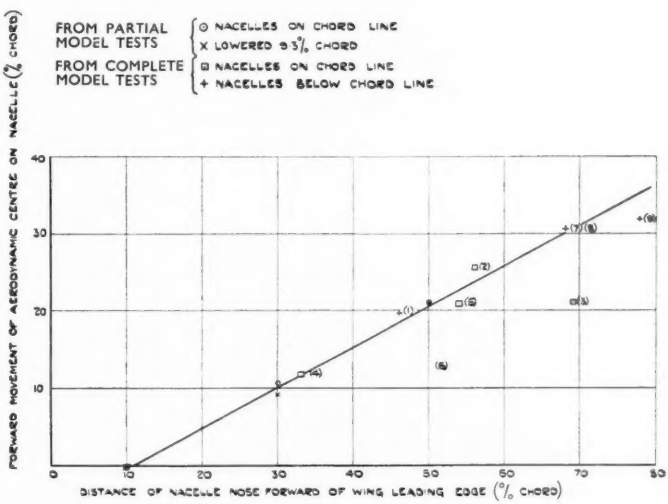



FIG. 7.

*Change in slope of pitching moment-lift coefficient curve, due to nacelle.*

We are left now with the measurement of pitching moment, with stick fixed. This is a quick and straightforward model test, and is one of the most valuable ones made in the tunnel. There is little scale effect on the position of the aerodynamic centre, at any rate on tests made above $R = 0.5 \times 10^6$, so that we have

considerable faith in the findings of our model tests, which can be compared with the elevator settings for steady glides at various speeds with stick held and airscrews giving zero thrust. We may ask why it is still necessary to measure longitudinal stability. We know pretty well the aerodynamic centre of a wing; we have from systematic model tests a method of estimating the forward movement due to nacelles (Fig. 7), and less accurately the forward movement due to the body. It is less easy to estimate exactly the downwash angle at the tailplane, particularly when the wing circulation is disturbed in front of the tail by the body and often by flaps with a central gap. And it is not possible to estimate at all accurately the interference on the tail from (for instance) engine nacelles. Since an accurate answer is needed, it is therefore still advisable to make model tests. These may show that the C.G. position (or tail size) must be altered to increase the stability over the whole range, or they may show that the tail is passing into a wake which reduces the stability over part only of the incidence range, and indicate the need for a change in tail position or cleaning up or diversion of the wake.

In fact, this very simple test has proved so useful that we tend to feel resentful when a more complete study of the factors involved proves necessary, and dynamic factors, for instance, need to be considered.

(3) The Cooling System.

In assessing from model tests the merits of a particular cooling system, our starting point is the cooling requirements of the full-scale engine or radiator. For most of the engines used in present-day aeroplanes, we know rough values of the pressure drop across the cylinders or the radiator matrix, and of the rate of air flow necessary for cooling. On our model we represent the engine by a baffle plate giving the right pressure drop; adjusting the exit area of the cooling duct will then give the flow appropriate to any flight speed.

In high speed flight we are primarily interested in drag. The part of the cooling drag, due to the cooling flow over the cylinder barrels or radiator matrix, is beyond our control, this part is easily calculated from the full-scale cooling characteristics. We can deduce from total head and velocity measurements at the entry and exit of the cooling duct what is the actual drag inside the engine or radiator passage; and it is the reduction of the loss which is found by this comparison with which model tests are concerned. Much of it is due to poor entry design. The " tired " cooling air coming from the exit duct may cause drag if it passes over body-wing or wing-nacelle junctions. The choice of entry and exit positions and areas, and the design of suitable entry fairings all fall within the scope of model tests; and whilst separations are more vigorous on the model, so that the measured losses are too large, good design on the model will remain good on the full-scale aeroplane. Occasional cases have been found in which the model tests suggested an appreciable loss which was not in fact found full-scale, but the opposite should not occur.

Questions of engine cooling at low flight speeds have grown in importance recently. With engines developing ever increasing power in the same small space, it has become a matter of touch and go whether the cooling flow during slow full-power climb is adequate. If the engine characteristics are sufficiently accurately known, the model will indicate the margin of safety possessed by the cooling system in this respect.

Finally, the cooling system may reduce the maximum lift of the wing. Pitot entries to cooling ducts placed in the leading edge of the wing, for instance, can cause a substantial reduction if poorly designed; but more frequently the reduction is a result of cooling air at low velocity being directed over the upper surface of the wing, as in a radial engine with gill cowl mounted centrally ahead of the wing. The scale effect on such measurements is probably large, and in this case small tunnel tests should be taken as a warning that the matter needs investigation at a higher Reynolds number.

(4) Balancing of Control Surfaces.

This question of aerodynamic balancing of control surfaces is of the very greatest importance, as it is perhaps the feature of design of which the pilot is most constantly conscious. With rising speeds, the band between which the control is neither dangerously light (or worse still, unstable) nor too heavy for the pilot to operate with comfort is getting narrower. Whereas years ago we used to reduce aileron hinge moments to half or even a quarter of the unbalanced moment, now the limit may be 10 or 5 per cent. of the unbalanced moment. The situation is most acute in the case of ailerons, though elevators too need close balance in some cases.

Though we have been using for so many years the type of control surface which has the hinge set back, and either a symmetrical or Frise nose, I think many here will feel a sense of disappointment that this question of the close balancing of such surfaces has not yet been placed on a more firm and satisfactory basis. If anyone should say to me, " My ailerons on my last aeroplane are working well; but I want the best I can get on my new design. Do you think a fatter nose "—or some such modification—" would improve them?" I should always say, " If you have a good one, stick to it." And that is not a healthy state of affairs. If anyone asks me to test their new Frise aileron design, I always try to dodge the test. I have been trying to analyse why this state of affairs has arisen.

To begin with, if I get a good carpenter—say, a pattern maker—to make me two wooden ailerons from the same drawing, which are hinged to be closely balanced, I do not get the same result from either aileron. It is in particular extremely difficult to repeat the hinge moment with aileron at 0° on two supposedly similar models. This is also the case full-scale, and arrangements are made to adjust some small trimmer to correct for this on the particular aeroplane. I remember a particular case in which we had a full-scale wing to test in the 24ft. tunnel, and made a one-fifth scale model to the drawing from which the wing had been made. On measuring up, certain small differences in nose shape were found, and a second model was made to the measured dimensions. The difference in hinge moments between these two one-fifth scale models was greater than that due to the major modification which we were to investigate. We also showed reasonably good agreement between the full-scale wing in the 24ft. tunnel and the one-fifth scale model made similar to it, and unanimously announced that the aileron was unstable for fairly small movements, when in fact in flight this was certainly not the case.

I therefore developed a view that because it was difficult, it must be wrong to carry aerodynamic balance to such extremes!

Having confessed my own disinclination to attack this question, let us consider the reasons for this baulked feeling. Obviously this is a case where either we have some variable not under control, or we have omitted some essential variable from our consideration. Some most interesting tests are in progress at the National Physical Laboratory in which the pressure over the forward balancing area is genuinely under control (*i.e.*, all the gaps concerned are most carefully governed, and there are no unintentional leaks into the curtained chamber in which the balance moves). Already the results look much more systematic and less kinky than our ordinary tests, suggesting that we have not in fact had this pressure sufficiently accurately determined. And there are plenty of variables which have not yet been systematically investigated. Tailplanes are getting thicker, elevator chords increasing, elevator nose shapes are varying. And from the full-scale side, there are friction, cable stretch, distortion of fabric surfaces under load, leak systems from the wing interior to the gap by the aileron nose. I think the time is ripe for a really systematic scheme of tests, taking the greatest care that the conditions are really under control. These tests should be made on really large partial models, and checked at the full-scale Reynolds number. It must be possible to isolate the effects in this manner, whereas the collection of

*ad hoc* tests in which many variables are altered may fail for a long time to supply the required clue.

(5) Measurement of Maximum Lift.

Another subject on which the designer may need information is on how to get high lift for take-off and landing. It is, of course, not possible to measure maximum lift in a low Reynolds number wind tunnel, and the main data must come from compressed air tunnels, full-scale tunnels, or flight tests. But even so, a designer can use his tunnel to help him apply these data. Since his primary information will come from a specialised tunnel which must do general tests, he will have to adapt this information to his own use. Suppose, for example, that he knows the front slat setting which is best with a given unflapped wing, and now wishes to use a slat in front of a wing with a Fowler flap. Wind tunnel tests may tell him that he needs a larger gap between slat and wing in this latter case, and he could confidently increase the gap. Or supposing he does not wish to bring slotted flaps close in to the body because of his fillet design, a model test will give him a very good idea of whether in his particular case it is worth bridging the gap or not. Furthermore, model tests will tell him how his high lift devices are affecting the stability.

I have said that we cannot measure maximum lift in our ten-foot tunnel; but now that we have a certain volume of C.A.T. tests showing us what type of scale effect to expect from what type of wing, we can do preliminary work even on maximum lift. My fellow wind tunnellers know that though we cover ourselves as far as possible by reference to high Reynolds number tests, we do in fact go on designing mixtures of slots and flaps and trying them in our own tunnels. I think myself that we should restrain our enthusiasm and maintain a very cautious attitude if we get far from a type which has already been tested to high Reynolds number. Apart from scale effect, we are in danger of being misled by tunnel wall effects. If we make our tests on a rectangular aerofoil in a closed tunnel, the tunnel wall interference increases the incidence more at the tips than at the centre of the wing. In our attempt to get high Reynolds number, we are likely to have made our wing as large as we dare, and we have evidence in the old 4ft. and 7ft. tunnel days of maximum lift measurements 16 per cent. higher in a small closed tunnel (wing chord one-eighth tunnel span) than in a larger one. As far as our tests have gone, an open jet tunnel seems to give nearly the free air value of maximum lift deduced from closed tunnel tests provided that the size of model is kept moderate. But if we have a closed tunnel, probably the best technique is to compare our new device with some known high lift arrangement. In some ways, using a two-dimensional wing spanning the jet is preferable—the tunnel wall effect is thus obviated. But there are practical difficulties; for one thing stubs fixed to the walls are used because of the poor velocity distribution in the boundary layer near the wall, and these are slow things to adjust; for another, the gap between wing and stubs must be kept constant and small (or sealed by some flexible material). The gap may be kept constant and very small by using a " steady frame," tying the model to plates restrained by air bearings. But these methods are elaborate, and as a practical measure I recommend that we all check our high lift devices against one of the aerofoil sections with split flap which have been tested to high Reynolds number in the C.A.T., using identical methods in each case, as I do not myself believe we can get absolute values which are comparable from different tunnels and different techniques.

(6) Other Types of Tests.

I am not going to make any attempt to enumerate all the types of test which are useful to the designer. Rolling and yawing moments due to ailerons, rudder power and yawing moment due to sideslip, and many other important types of test must be passed over. But I must give passing mention to one type of work

which is likely to take up an increasing amount of time in the designer's tunnel. I refer to the measurement of local pressure distribution for stressing purposes, as for example the loads on such surfaces as cabin windows, undercarriage doors, etc. Until a year or two ago, such stresses were handled comfortably by the minimum gauges of material necessitated by manufacturing conditions. Nowadays, however, dynamic pressures of the order of 300 to 400 lb./sq. ft. have to be met, so these stresses must be estimated with fair accuracy if weight is to be kept down. Pressure holes can be put into the model already used for the other tests.

If, however, pressure distribution is needed on (let us say) a rudder or elevator horn on which the pressure variations are rapid, the largest possible model is usually the best. High Reynolds number is desirable if balance surfaces are in question, and large size is wanted to get a large number of tubes into the model without the expense of fine workmanship. Half of a 14ft. span tailplane fixed to the tunnel wall would be a suitable kind of model.

Hinge moments can sometimes be deduced more conveniently from pressure plotting than from direct tests—as, for example, on the variable gills of a cowl.

## Part II.

### Other Types of Tunnel.

I have purposely not discussed the smaller, low power tunnels, because we have after all had twenty years to meditate on their shortcomings, and it is finding their limitations which has driven us to the larger sizes. The only remark I would make about the smaller tunnels is they can be of almost equal use provided that more intelligence is put into using them and more tests are made. (For example, a single test rig of an 8ft. span model may suffice, whereas a complete model test plus partial model tests of nacelle and cooling may be needed if only a 4ft. span model can be used.)

I want now to look the other way, at the larger or more elaborate types of tunnel and testing.

### Compressed Air Tunnel.

The most direct extension to our atmospheric tunnel test is the high Reynolds number test in the compressed air tunnel. This is our reference and standby in our model work, as it sorts out for us the effect of Reynolds number from the many other differences between model tests and flight conditions. It is our main means for studying maximum lift. It has the same problem as to transition points and turbulence, and its results are affected by the kind of difference in surface finish of the model which can easily occur, so that valuable systematic results on the effect of roughness can be obtained. The kind of drag questions which can be answered on partial models in the atmospheric tunnels can be more authoritatively answered on the complete model at high Reynolds number in the C.A.T. It is quicker and easier to work in an atmospheric tunnel, and the C.A.T. is rather the place to check the more important results than an alternative to the other small tunnels; it is because we have the compressed air tunnel as reference that we are able to do so much work in atmospheric tunnels.

### Large Tunnels.

The C.A.T. is restricted in the same way as the small atmospheric tunnels in using small rigid models. A great step is taken in having a large tunnel in which the actual article can be tested. The N.A.C.A. have gone the whole way towards correct representation of, at any rate, the smaller types of aeroplane by building their 60ft. × 30ft. tunnel. Here stalling problems can be dealt with at the full Reynolds number.

With our 24ft. tunnel we are in the state of the man with the 5ft. tunnel instead of the 10ft. one; with ingenuity we can cover most of the same range.

The main work for which this tunnel was built was the testing of engine nacelles, and here again a " partial model " technique is used, with a real engine and airscrew. This tunnel gives the quantitative values of pressure drop across the engine and cooling flow which we assume in our small tunnel tests. This tunnel has also shown most convincingly on full-scale engine installations the large drag losses due to leaks.

### High Speed Tunnels.

The Society listened last session to a lecture on the important results which were coming from high speed tests made in a 1ft. tunnel, indicating the limits which seem (I think, most mercifully) to be set to flight speed as compressibility effects become more serious. Here, as usual, in order to make progress, it is necessary to isolate the thing we wish to study. It is only possible to drive a 10ft. high speed tunnel with a reasonable horse-power by reducing the air pressure, and since the velocity of sound is not primarily affected by pressure, we intend to study high speed at a low Reynolds number. There will, obviously, be need to check the validity of this course of action, and the results which will accumulate from the larger high speed tunnels abroad and later here in England will aid the designer in making the aeroplanes which will eventually check their results in high speed flight.

### Free Flight Tunnels.

At this stage we break away from the limitations we have hitherto imposed on our model by fixing it or constraining it to move in some predetermined manner (such as a steady state of roll, or an oscillation). In the vertical spinning tunnel we make the velocity of the rising jet equal to the rate of descent of the spinning model; in a flight tunnel the jet must be tilted to give the required gliding angle, and the velocity adjusted to the angle. The model in either case can (if stable) take up a steady motion, from which it is displaced by operating one of its control surfaces by a timed mechanism or distant control.

The spinning tunnel is known, in spite of its low Reynolds number, to have indicated in many cases what modification will improve an unsatisfactory aeroplane. Spinning is a singularly difficult subject to study, since the same aeroplane may be put into spins of different type, and it may happen occasionally that a dangerous spin is found in flight and that in the tunnel another type of spin is entered. But in spite of its limitations, dangerous tendencies have been observed in the tunnel, found to be present in flight, been removed by modification in the tunnel, and the same modification has made the aeroplane safe in flight.

The free flight tunnel is in its youth, and we must wait to see what the N.A.C.A. workers can do with it.

### Conclusions.

I would summarise the use of model data by the designer under three heads.

Firstly, there is the *ad hoc* work carried out by the designer in his own tunnel. This will start with model tests to fix doubtful points as to the design, to compare, for instance, alternative nacelle arrangements. When these points have been decided, a complete model will be tested for stability and control (*i.e.*, power of control surfaces, settings to trim with and without flaps, etc.). At this stage pressure measurements will be made for the stressing section.

Another burst of activity may follow the first flights, when the wind tunnel may be called upon to deal with any one of a hundred problems from a fundamental instability to the pressure on an inspection door which is mysteriously missing after the flight—and will probably be discovered eventually under a bench.

One over-riding condition of these designers' tests is that the average time one model occupies the tunnels is four to five days. The designer is, and can afford to be, " scrappy " in his programmes because he has such an immediate

correlation between model and flight tests. He can use empirical methods of correcting his model results to full scale, which in fact cover peculiarities of his tunnels and technique, and also cover his average surface conditions and liability to have leaks.

Secondly, there is systematic testing to give a body of information showing the type of variation following from making given modifications. This common fund of information should save the need for many specific tests which would otherwise be needed. To form intelligent programmes of such tests requires the closest co-operation between the designers and the establishments who will in the main carry out these tests. We are indebted to America for the major part of our systematic information; and though we are indeed grateful to them for placing this at our disposal, I think myself that there is need for more of our own systematic work, perhaps not so wide in scope but concentrated on our own immediate problems. It is essential that this work should be centred round the best new designs, and (again speaking for myself only) I should like to be able to take the interesting new designs, to make a programme in consultation with the designers working on similar ideas, and to do what you might call systematic *ad hoc* work rather than to test Mr. A and Mr. B's models.

Thirdly, I would make what must be very inadequate mention of one less direct way in which model work can help designers. There are problems which can only be solved by prolonged research and theoretical work. In many cases only approximate methods of theoretical attack are possible, and tunnel tests directed to confirming or disproving the assumptions used can be of great value. The study of boundary layer flow and of turbulence is still in the " symposium stage " when debates on fundamental assumptions are often vigorous. But the " transition point " is now a familiar concept, and its determination has turned drag measurement in various tunnels from a dark mystery into a rational business. Boundary layer control in the full sense of maintaining a laminar layer is still a dream, but separation control is now practical politics. And assisting in the long range researches may be the most important part of tunnel work. This work is perhaps specially suited to Universities.

I have kept for the last words of my paper a quotation from a paper given before this Society in 1927 by Mr. Pierson on " The Use of the Wind Channel for Performance Prediction."

" If the design is completely new, difficulties in estimating this performance are at once apparent; chiefly owing to our inability to make correct allowances for the effect on lift and drag of such variables as centre section cut-out, external wing tanks, radiator position, body streamlining and the various interferences attached to these. . . .

" All these factors can be taken into account by a wind channel test on the complete model of the proposed machines. . . .

" The usefulness of the prediction depends entirely on the accuracy of agreement with full-scale tests. We have found that the agreement is good for all types. . . . We do not find that any useful purpose is served by splitting up the lift and drag of the whole machine into their various components, even if time were available for the labour involved."

Alas! the golden age when " the agreement is good for all types " has passed. But in spite of this, I think we can feel that by reducing our claims and understanding our limitations the scope of model testing is still sufficiently wide to give us work until this subject is again before the Society's attention in another ten years' time.

## Discussion.

The Chairman: The authors had given a most impartial review of the subject of wind tunnel tests on models, and whilst they had emphasised the value of those tests, they had, at the same time, frankly stated their limitations.

A question, which often perplexed the layman, was that whereas the speeds of aircraft had increased greatly during recent years, nevertheless the air speeds in normal tunnels were practically constant. He asked whether that fact did not reduce somewhat the value of the experiments in the atmospheric tunnel.

Finally, commenting that the authors had very wisely emphasised the importance of noting the combination of the facts, he said that he remembered occasions on which he had had to struggle with reports in which so many variables had been introduced that it was very difficult to correlate the facts.

Mr. H. E. WIMPERIS, C.B., C.B.E., (*Fellow and Past-President*): He expressed again the profound regret of all present that Miss Bradfield had been unable to attend on an occasion which was unique in the history of the Society. He had been particularly desirous of hearing Miss Bradfield give her lecture, because there were certain things he had wished to say in her presence. Miss Bradfield had been engaged on aeronautical research work for the last 20 years, and during the time when he was in charge of the scientific research staff he had been very impressed indeed by her skill and energy, by the thoroughness of her work, and by the amazing degree of confidence she had won among the industrial firms in this country; any designer who relied upon her advice seemed to be entirely confident that he was really getting the facts he wanted; Miss Bradfield's accuracy had become almost a by-word. In the last paragraph of the paper the authors had stated " Alas! the golden age when ' the agreement is good for all types ' has passed." But he ventured to disagree with that, because all types were present at the meeting and they were in general agreement in their admiration for the way in which Miss Bradfield and her associate had described the results of their collaboration.

It would be fair to say that, in the general advance of engineering investigations, aeronautical research was a kind of spearhead, perhaps not because those engaged in that work were so much brighter than the rest of the world—although there was something in that—but because they had to work under much more difficult conditions. He had in mind the drastic weight limitations which concerned all aeronautical work, in a way remote from most engineering enterprises; most of the engineering structures discussed in the hall of the Institution of Mechanical Engineers, in which they were that evening, involved weights which aeronautical workers would regard as exceedingly cumbersome. If aeronautical science were the spearhead of the attack on the unknown, one of the most fruitful phases of it was the work on models, such as had been discussed in the paper. It was true that the results had been difficult of interpretation, and the authors had stated that they had passed from the days of optimism, when they had thought they knew everything, to the days of pessimism, when they were convinced that they knew nothing; and he supposed that at the present time they could modestly say that they knew a little. But the interpretation of the results was becoming more difficult because aircraft speeds were increasing very rapidly—although, as the authors had humorously put it, there was a merciful limit to the extent to which they could go. But, considering speeds of to-day and in the future, there was a great lack of knowledge as to what was happening, as to why and how it happened, and whether it always happened in the same sort of way. It was true that the new, very big and fast tunnels should throw light upon the subject, and, as the authors had said, the reduction of the density of the air did not affect much the velocity of sound (in fact, did not affect it at all), so that high speed influence should be prevalent despite the low pressure.

Commenting on the suggestion in the paper that the extra induced drag due to lowering the nacelle could be cured by merely curling down the trailing edge, Mr. Wimperis said it was new to him, but it was certainly very ingenious.

In discussing the cooling system, he continued, the authors had stated that the "tired " cooling air coming from the exit duct might cause drag if it passed over body-wing or wing-nacelle junctions. He believed he had an idea of what

the authors were driving at, but he invited Mr. Ellis to explain what he thought was going on in the air to make it so tired and so troublesome.

A statement in the section of the paper dealing with drag due to leaks had rather puzzled him. It was stated that " alternatively, the leaks must be made to open in a backward direction, in which case they will not cause a high internal pressure. . . ." He did not suppose that they would; he would have thought that that was just the way in which to get rid of high internal pressure. He asked whether the authors really meant what they had stated, or whether they meant something quite different, and if the latter, he would like to know what it was.

Mr. ELLIS: Replying to the Chairman's point with regard to the size and speed of aeroplanes " running away " from the models, he said that that fact was driving us to the use of larger and larger tunnels. At one time 4ft. tunnels were regarded as being quite reasonable, but nowadays research workers preferred to trust tunnels of from 7 to 10ft. The point made by the Chairman was also one of the reasons why partial models were used; by that rather underhand device, research workers had caught up a little leeway. Perhaps in time it would be necessary to use only compressed air; that would be very terrible.

Dealing with the point raised by Mr. Wimperis about restoring the lift by modifications of the trailing edge, he said that it was quite straightforward. The drag occurred because the nacelle, as it were, knocked a lump out of the spanwise lift distribution. Considering the very extreme case of a twin-engined monoplane with very bad nacelles, it would effectively have three wings, each with very much reduced aspect ratio, and there would be six sets of wing tip vortices all producing induced drag. If that local failure of lift could be avoided, the induced drag would not arise, and that could be effected by deflecting the trailing edge somewhat.

The reference to " tired " cooling air was not his own definition, but the term was used to describe air whose energy was much reduced. Perhaps that had arisen as the result of thinking in terms of fixed models in a moving air stream. If one were thinking in terms of an aeroplane actually in flight, where the air was stationary and the aeroplane was moving, one would describe the " tired " air as air which had been deflected forward. But since the authors were thinking the other way round, the air must be regarded as having lost a good deal of its energy; it meant that the boundary layer, from which the greatest amount of drag arose, was very much thicker than it would be if the tired air were not there.

Backward opening leaks represented a subterfuge to avoid leak drag. One would use them where perhaps normal construction would produce a forward facing leak, or in other words, a pitot entry. That would not produce drag unless connected up inside to a rearward facing entry or flush entry.

Mr. J. D. NORTH (*Fellow and Member*): He congratulated the authors on having stated very fairly the case for the use of the wind tunnel in design, and said that the situation had remained very nearly stable so far as the small atmospheric tunnel was concerned, at least for the last five years. Induced interference drag was measured in 1916 or 1917, but at that time it was not recognised as being there. There was a report of a test carried out at the National Physical Laboratory on one of the R.E. twin-engined models which had a nacelle on the top of the wing to house a gunner; the figures of lift and drag, with and without nacelle, were given, and contained all the evidence of the existence of induced drag. Many years afterwards, when such effects were noticed in flight, investigators reverted to tunnel tests and looked up reports, and had found the evidence of the existence of induced drag, although it had not been recognised until then. The significance of that type of interference had been overlooked, in spite of the evidence which had existed.

Mr. North asked why it was not considered possible nowadays to measure $M_q$, and he added that in the very early days, one had measured oscillations and

damping in the apparatus, but the forced oscillation method which had taken its place had given results which were at least in reasonable quantitative agreement with deductions from flight observations.

Mr. North emphasised very strongly the great extent to which misleading measurements were made of interference, prior to the recognition of the effect on interference of moving the transition point. He suggested that the recognition of that had done as much to clear up misconception concerning the effects of geometrical alterations, as the Lanchester-Prandtl theory on the quantitative basis had done to clear up a lot of ideas on plan form.

A matter with regard to model shapes and their resistance which was not mentioned in the paper, but which caused him some anxiety, was that the stability of flow around a body appeared to change with Reynolds number. In other words, the form drag of shapes changed with Reynolds number. As had been rightly said, in the smaller models, if any one of them proved to be good in the small tunnel, it would probably be good at the full scale, but not vice-versa. Probably a great deal of simplification from the structural point of view, with possibly a considerable saving in the man-hours spent in producing an aeroplane, could be effected if we could use geometrical forms which were satisfactory at high Reynolds numbers, but were not shown to be good at Reynolds numbers other than those obtainable in the compressed air tunnel. In that connection, Mr. North exhibited a diagram from one of the R. and M. Reports (T. 3508) showing the drag of a large number of struts of all kinds of sections, from the streamlined to the ellipse. The figures were plotted on the basis of log $Vb/n$, and the struts were all produced on a constant basis. As a general indication, it showed that as the Reynolds number increased, it did not matter very much how the strut was shaped, provided it was smooth. Some of the high figures at the bottom of the diagram represented ellipses and there was a fairly wide difference of fineness ratio in the struts.

He emphasised that the difficulty was to know the effect that small projections might have upon shapes, and also the effects of departures of the shapes from the ideal streamline. The shapes became more stable at high speed. How could one determine whether the stability of the shapes was such as to withstand the effects of small excrescences or small departures from the proper shapes? That was one of the most difficult problems confronting aeronautical science to-day.

Mr. ELLIS: The chief trouble in connection with the measurement of $M_q$ was that, in order to do it accurately, one must have a model which was free not only to oscillate about a transverse axis, but to oscillate vertically as well.

With regard to the change of form drag with changing Reynolds number, he believed Mr. North's point was that when one reached really high Reynolds numbers, one could build up a form from a cylinder, a cone, and a hemisphere, instead of bothering with double curvatures and such-like complicated structures.

Mr. NORTH: That was partly the point; there was also the consideration that the flow around it might not be very stable, and might be disturbed very easily.

Mr. ELLIS: The reduction of the drag of a mediumly poor form to that of a fairly good form at high Reynolds number was due to breakaway effects being reduced at high Reynolds number, rather than to a reduction of true form drag; the form drag would still be high at high Reynolds number, but the poor form might have, in addition, a turbulent wake from breakaway at low Reynolds numbers. That was one of the points that had been brought out by the work in the compressed air tunnel.

Discussing the effect of excrescences, he suggested that the safest plan would be to assume that they were bad, especially if the flow condition was at all sensitive. Quite small excrescences could do a great deal of damage if they happened to be in the critical region. However, he would prefer not to commit himself very definitely on that matter.

Mr. R. K. PIERSON (*Fellow*): He agreed that model tests could give the right answers if those tests were properly carried out, but he emphasised that the models must be truly representative of the full scale. He asked what the authors considered to be the lowest Reynolds number that would give reliable results up to, say, 0.8 $C_L$ for drag, lift and pitching moment.

He suggested that experiments in connection with hinge moments should be carried out in the 24ft. tunnel at the R.A.E., and he would have thought that it would have been found desirable to employ a night shift on that tunnel in order that more work could be done.

He agreed that the wind tunnel could be used to advantage for stability work, but was of the opinion that, in estimating the performance of modern clean aircraft, more reliable results were obtained from calculations on a skin friction basis than from tests on small scale complete models, allowance being made for cooling and gun turret drags from tests on large scale partial models in the 24ft. channel.

Mr. ELLIS: Replying to the question as to what was the minimum safe Reynolds number for drag tests and tests in general, he said that in regard to drag it was difficult to specify a critical Reynolds number, and one should use as high a Reynolds number as possible. There was a critical Reynolds number with pitching moments, and that was round about half a million; so long as one exceeded that value for the wing, pitching moments were fairly reliable.

Mr. A. E. RUSSELL (*Fellow*): He asked that if it was assumed that the wind tunnel could be relied upon to give an accurate measure of form drag, why is it that the tunnel does not give the correct increase in drag with increase in wing thickness? Or does it, if the transition point is fixed on the leading edge? He also mentioned that he believed that the pitching moment curve could be used as an indication for possible tail vibration. A kink in this curve showed that the tail was passing through a turbulent wake. He asked whether the authors had had experience of an actual case of vibration being cured by experimenting in the tunnel until a smooth pitching moment curve was obtained.

Mr. ELLIS: The increase of wing drag with thickness had been measured in tunnels, and he believed that the most consistent results on that subject were those obtained from the D.V.L. Admittedly the models were of large scale; he was not sure what size of tunnel was used, but it was something almost equivalent to the 24ft. tunnel, and there was an increase of drag with wing thickness corresponding fairly well to full-scale figures. It was perfectly true that kinks in the pitching moment curve often indicated that the tail was going through a wake from the nacelle, and that in such a wake it was liable to suffer vibration from buffeting; and there had been cases in which the elimination of the one had cured the other.

Mr. H. KNOWLER (*Fellow*): The authors, in their opening remarks, had defined the designer's attitude to wind tunnel work, and he gathered that the paper was mainly an exposition of how to correct or " cook " the results so that they could be assimilated by the designer.

But he agreed with the view that model results, in the main, were rather pessimistic as compared with the results obtained with the same design on full-scale. Models seemed to suffer from the point of view of directional stability. If a model were left free to rotate in weather-cock fashion in a tunnel, one might be a little frightened by the results. A machine which had flown quite successfully might be thought to be unstable if an exact model of it were tested in a tunnel in which it was free to move in weather-cock fashion.

On the other hand, he believed that trouble had been experienced in regard to directional stability in a number of large machines, and particularly some of the large American machines, although the Americans spent money lavishly on wind tunnel tests. Some had developed from one fin and rudder to two fins and rudders, and even three fins and rudders. He would be glad if the authors could throw some light on this apparent discrepancy.

Mr. ELLIS: Dealing with the accusation that wind tunnel results were "cooked," he said that much depended on the definition of "cooking." If one could place a model in a wind tunnel and obtain from it immediately a complete answer to one's problems, without having to make any corrections, aircraft manufacturers could probably dispense with the services of the whole of their design staffs, except for perhaps one man in each works to manipulate a slide rule!

With regard to weather-cock stability, he said that if a model were allowed to move freely in a tunnel it would probably oscillate. He had not experienced much trouble in that direction, but he suggested that the reason why oscillations appeared to be much more violent in a tunnel model than in a machine in flight was that the ratios of moment of inertia to damping and yawing moment "stiffness," and so on, were widely different.

He believed that twin fins were used mostly on multi-engined aeroplanes; and quite a number of factors arose there. The main factor, perhaps, was to maintain a fair amount of directional control when one engine failed. In one case, he understood, multi fins had been used because a single fin would have been too big to enable the machine to go into the hangar.

Mr. W. H. SAYERS: The authors had given an exceedingly able exposition of the usefulness of the wind tunnel to the average designer; and perhaps they had placed the requirements of the designer rather high. They had stated that with a 5ft. tunnel, if one used a little ingenuity, one might do almost as well as with a 10ft. tunnel; his own impression was that one could get, out of a 5ft. or even a 4ft. tunnel, practically everything that one could get from a 10ft. tunnel without applying an enormous amount of ingenuity. Perhaps the only instance in which one experienced real trouble in the use of a small tunnel was when trying to explore the effects of small details; on the biggest size partial model that could be used in a small tunnel the details were too small to be representative, and one could not make those details representative even on 10ft. tunnel models, because the Reynolds number was so far from the true one.

Recently he had been engaged in making probably the biggest wind tunnel model yet made in this country. It was the biggest complete model that could be accommodated comfortably in the 24ft. tunnel, and he was doubtful as to whether even the 24ft. tunnel would tell him what he wanted to know, because certain items on the model, whose effects he wished particularly to explore and which were in the nature of protruding gun barrels, were still in the transition region at the highest speed in the 24ft. tunnel. The real trouble to-day was that, whilst the compressed air tunnel would tell us the truth about a smooth model at somewhere near our maximum speed conditions, unfortunately we did not fly smooth models. The 24ft. tunnel would give results on partial models; but again, we did not fly partial models. We had not anywhere in the world a tunnel in which representative size working models could be tested. From the small tunnel and from the compressed air tunnel we could obtain results which did not quite represent the truth. To-day one could use a 4ft. or 5ft. tunnel for all the work that could usefully be carried out in a small tunnel, work such as finding out whether the general layout was right or whether there was anything silly about a design which would upset its performance very badly. If one were satisfied in that respect, one could estimate from available drag data the likely performance; and if one wanted a check, one could obtain re-assurance by using the compressed air tunnel. The performance of the machine would be rather less than that indicated by the compressed air tunnel and rather better than that indicated by the small tunnel.

His personal view was that we did not want a lot of 12ft. tunnels (though they would save a lot of trouble in model making), but that we should have a few 30ft. tunnels, and at least two 60ft. × 30ft. We should then know something about the performance of aeroplanes before they were actually flown.

Mr. F. RADCLIFFE (*Associate Fellow*): He asked for a little amplification of the paragraph under the heading of "High Form Drag," dealing with the fixing of the transition point of fuselages or nacelles or other items to be tested. He could not quite appreciate the exact meaning, and asked whether the reference was to the transition from laminar to turbulent flow or to the fixing of the transition point more forward on the body itself.

Discussing paragraph 1.3 on "Extra Induced Drag," he asked whether the theory mentioned therein, which was very well known, had been confirmed by actual tests. Could the actual lift be reinforced to give the lift of a normal wing by curling down the trailing edge?

Finally, he confirmed, from information he had received, that the three fins and rudders used on the D.C. 4 were determined almost entirely by hangar dimensions; but for that consideration, the machine would certainly have had two fins and rudders instead of three. It would be rather interesting to note the reaction in this country.

Mr. ELLIS: The transition point mentioned in paragraph 1.2 was, of course, the transition from laminar to turbulent flow. But he suggested that Mr. Smelt, who was more familiar with that part of the work, might care to reply to Mr. Radcliffe.

Mr. R. SMELT: The transition referred to was that from laminar to turbulent flow in the boundary layer; and the aim in model tests was to fix this in a known position. With regard to a trailing edge flap for lift restoration behind a nacelle, the idea has already been shown to be practical by tunnel tests, both on small model nacelles and on a full-scale practical installation in the 24ft. tunnel.

Mr. S. SCOTT HALL (*Associate Fellow*): Discussing longitudinal stability, he said he had understood Mr. Ellis to say that conditions in flight lay probably between the stick-fixed and the stick-free conditions, but tended towards the stick-free condition as loading increased. He asked Mr. Ellis to explain his reasons for that.

Mr. ELLIS: In stating that the stick-free stability tended to become more important he had not meant with increase of loading, but with increase of speed. If the speed of a given aeroplane, with a given degree of balance to the elevator, were considerably increased, the compromise in stability as between the stick-free and stick-fixed conditions would become much nearer the stick-free condition. Taking the extreme case where the speed was very high, the hinge moments could be such that the pilot could not move the stick more than a fraction of a degree; whatever the pilot did, the stick would be virtually in the free condition. At the opposite extreme he could keep it near the stick-fixed condition.

However, those were his personal views, and he would be very glad to hear other views on the subject.

Mr. L. W. BRYANT (National Physical Laboratory) (*Fellow*): Discussing stability, he agreed that the simple test of lift, drag and pitching moment on a complete model and on the model without its tailplane must continue to provide a most important fundamental basis on which to build estimates of the changes in stability due to shift of C.G. and alteration of tail area. The simple tests, in conjunction with generalised tunnel data, would also help in arriving at the probable effects of slipstreams and of free elevators. In the past, satisfactory dynamic stability had been secured almost invariably by providing a stable slope to the static moment curve. But the low drag, high loading and high moment of inertia of modern aeroplanes had modified conditions, so that we might expect an unstable phugoid oscillation to be a much less rare occurrence than was the case formerly. The test for that dynamic stability involved a means of measuring damping in pitch. The method of oscillation of the model about a fixed axis through the C.G. hitherto employed was not satisfactory, notably because the vertical motion of the C.G. was suppressed, whereas in free flight vertical move-

ment of C.G. and pitching motion were correlated and had had a mutual interaction.

At the National Physical Laboratory it was proposed to try a new method of experiment which, at any rate theoretically, fulfilled the same function as a free flight model so far as longitudinal motion was concerned. The model would be given three degrees of freedom, along the wind, perpendicular to the wind, and an angular rotation in pitch. Thus, all the elements of the phugoid would be represented. The moment of inertia effect would be included, because the model was to be a dynamic one, with mass and moment of inertia correctly chosen to correspond to the scale of the model. Wind speed would be adjusted so that the model and part of the supports floated when undisturbed.

Similarly, high loading and high inertia in roll and, to a less degree, high inertia in yaw added to the danger of unstable lateral oscillations. The proportioning of wing dihedral and tail fin was a delicate art in those conditions. A technique on similar lines to that already described was on trial for lateral stability. A dynamic model was used and three degrees of freedom—sideslip, roll and yaw—were alone permitted. The experiment was in fact rather simpler than the longitudinal one.

It had been demonstrated that for that type of experiment a very steady wind was essential. It was hoped that the new tunnels under construction would enable the technique to be developed successfully. His own feeling was that, if that could be done, the partially constrained model would give results more easily interpreted than those obtained in the American free flight tunnel. He hoped that it would be possible to develop a type of test analogous to that of the spinning tunnel which would detect border-line cases of unstable oscillation. At the same time, he did not think the dynamic tests were likely to render superfluous the straightforward fundamental tests of pitching moment for longitudinal stability and yawing moment for directional stability. The dynamic tests would be necessary mainly to determine the effects of inertia. We should probably need some method of correction for Reynolds number based on experience.

Mr. E. Ower (*Fellow*): He suggested that the authors, in their efforts to be impartial, had been rather pessimistic about the value of overall drag tests. Speaking from his experience with the duplex tunnel at the N.P.L., in which the models used averaged about 8ft. span, he thought that, with the knowledge now available concerning transition points, etc., and by making use of one's own experience, one could get a fairly good estimate of the overall drag of the model. But whether or not one agreed with that view, one could still make out a good case for the overall drag test on the grounds that it was a very convenient method of indicating whether or not the lay-out of the whole machine was good aerodynamically. By fixing the transition point on the model with wires, one could be fairly sure what the skin friction drag of the model should be at the Reynolds number at which the test was carried out. To this estimated skin friction one would add a reasonable allowance for form drag, and if the measured drag were considerably above the sum of the two, one could be fairly sure that there were sources of high drag present. In that case, one could resort to partial model tests, to attempt a cure, but there would be no need to do this if the overall test showed the drag to be reasonable.

The authors had referred to the effect of changes of lift coefficient in partial model tests. If one worked at any appreciable value of the lift coefficient, it was necessary not only that the local lift coefficient of the partial model should be unchanged, but that the lift distribution should also be unchanged. One had to bear in mind also that the interference effect (of a nacelle, for instance) might extend out along the span for a considerable distance, and in fact involve a greater length of the span than one could get into the tunnel with a partial model of reasonable size. The possible effect of this on the final result had to be considered.

With reference to the point made by Mr. Pierson, that it was necessary to have models truly representative of full-scale, Mr. Ower emphasised the importance of having very well made models. The time spent in making a really first-class model was more than recovered by the saving of time spent in the tunnel; and the gain in accuracy was unquestionable. Moreover, it was important that there should be frequent personal contacts between the tunnel staff and the model-making staff during the time a model was being made. This was the only satisfactory way of ensuring that the model would be constructed in the manner that would best suit the programme of tests to be made. One could not expect a mechanic, working only from drawings, and without wind tunnel experience, to be able to settle satisfactorily the host of details which could make so much difference to the ease and accuracy of the actual tunnel work. At the N.P.L. it had been found that it paid very well, when a firm was making a model of one of its own designs for test, for the member of the staff concerned to make periodic visits to the firm to advise on constructional details of the model.

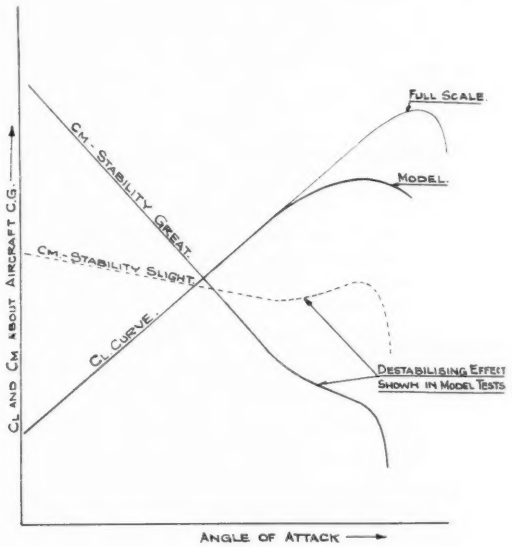



FIG. 8.

Mr. G. B. FENTON (*Associate Fellow*): He asked for the opinion of Mr. Ellis, in connection with atmospheric tunnel work, with regard to the interpretation of the pitching moment curve. When testing a model wing and fuselage, without tail, of about one-twelfth scale in an atmospheric wind tunnel at a wind speed of about 100ft. per second, or rather higher in some cases, he had found in a number of cases that the lift curve was, of course, straight at first, and then lost its linearity for a certain distance before the stall. With modern wing sections, assuming the model had a Reynolds number of .8 million and full-scale was of the order of 4 millions, the pitching moment curve might show a peculiar kink in the region just beyond the linear portion. He had experienced this, and presumed it was due to a partial stall at the root; and asked how to interpret the characteristic full-scale, since the actual angle of attack was different and the lift coefficient was different. If a sufficiently large tail were fitted to the model and the stability were high, the kink in the curve for the model would not be such as to lead to instability; but if the stability were slight in the first

place due to a smaller tail, instability might result. He asked whether that would indicate the same degree of instability in the full-scale aircraft. In other words, he felt that over the linear lift region, in the atmospheric tunnel test, one could interpret the pitching moment, but that when the region was reached in which the lift curve ceased to be linear and the results were not a true measure of the full scale angle or lift coefficient, one came to a bad region for interpretation. The curves are illustrated in Fig. 8.

Discussing the use of wool tufts in an atmospheric tunnel for observing the flow at or near the stall, he asked whether they were representative. He had used surface tufts in the tunnel, and also depth tufts at the ends of pins on the model surface, and from the results thus obtained had drawn pictures of the flow over the wing; he asked for enlightenment as to whether or not those pictures gave a true idea of the flow.

Mr. ELLIS: In regard to the question concerning the kink in the pitching moment curve, he felt that the interpretation of it must be an inspired guess. His own guess was that one would extend the pitching moment curve to correspond to the lift curve. It was very difficult to guess what to do if the particular job happened to be critical; but he believed it was safe to assume that the kink in the pitching moment curve was linked up with the change in the lift curve.

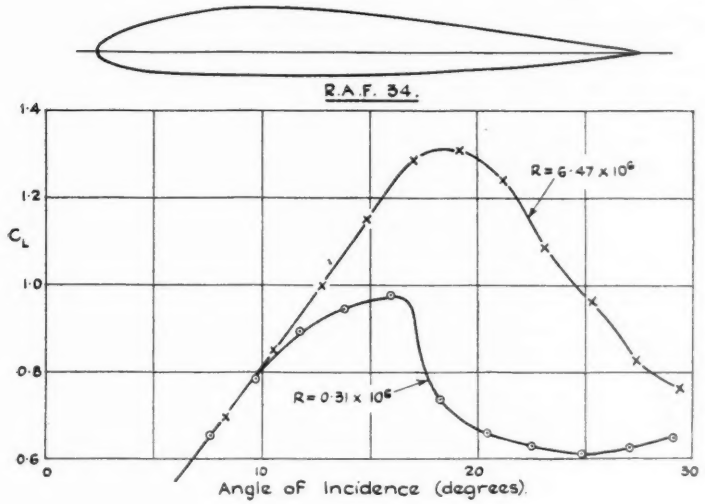
He believed tufts were very useful in showing up really bad features of design, such as serious breakaway at a bad junction between wing and fuselage or between nacelle and wing, and so on. He believed Mr. Irving had used them very extensively, but he personally had had very little experience of the comparison between model and full scale by means of tufts.

Mr. H. B. IRVING (*Fellow*): Dealing with Mr. Fenton's point with regard to the lift and pitching moment curves, he referred to the compressed air tunnel data of R and M 1706 for the lift of various wings and contrasted the lift curves for the R.A.F. 34 and the Clark Y.H. wings (Fig. 9). At the atmospheric pressure in the compressed air tunnel the R.A.F. 34 lift curve was rather straight at first, then it bent over and later there was a sudden drop. That curve corresponded to a Reynolds number of about $0.3 \times 10^6$. At a Reynolds number of about $6\frac{1}{2}$ millions one obtained a very nice gradual curve. In the case of the Clark Y.H. at atmospheric pressure, *i.e.*, low Reynolds number, one obtained a fairly smooth curve; but at full-scale, with Reynolds number about the same as before, the curve continued fairly straight at first and then dropped catastrophically, so to speak.

One could not avoid being rather pessimistic when confronted with two such completely different types of scale effect with two different wings; it seemed to indicate that the process of stalling in the two cases must be different. Therefore, it seemed that there was no guarantee at all that the kink in the pitching moment curve for the model, mentioned by Mr. Fenton, indicated the same kind of kink in the curve at full-scale. It might be the same, but it was quite possible that it would be different, because the process of stalling was different as between the model and the full-scale.

With regard to wool tufts, a large amount of work had been done, but nothing had yet been published, so that he could not say very much more about it; but the general position, as he saw it, was that on the whole the tufts on the model were fairly reliable as giving a rough sort of indication of the full-scale flow. One always had a feeling, however, that there might be cases where the indication would be wrong; the fact that fairly good agreement had been secured as between model and full-scale in some cases did not guarantee that there would always be good agreement. At the R.A.E. it had been found to be very important, in order to get the whole story, to use tufts, not only on the surface, but also on masts.

The written paper, he continued, bore very strongly the imprint of Miss Bradfield's forceful personality; there was no stilted terminology, but some charac-



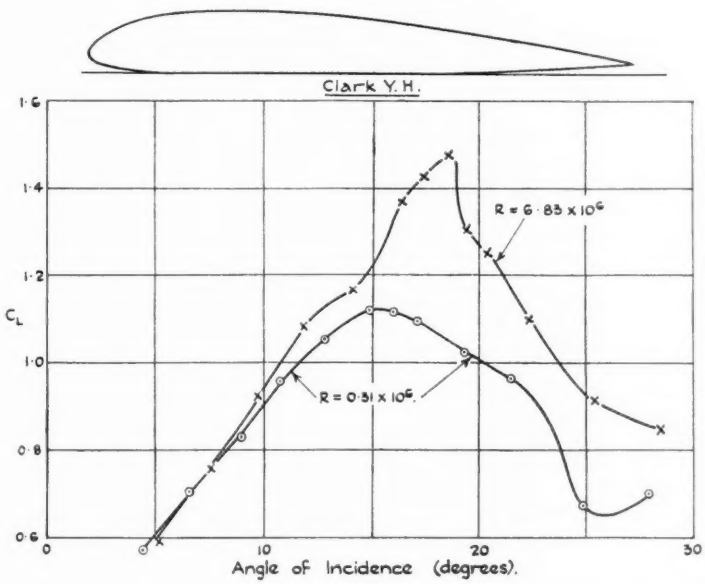




FIG. 9.

*Compressed air tunnel lift curves for R.A.F. 34 and Clark YH section.*

teristically expressive phrases. He liked particularly the reference to the transition point "hopping about without our knowledge." In that connection he recalled that when the airship model was sent all over the world and was tested in various wind tunnels, the drag results were simply all over the place; the Aeronautical Research Committee at that time had been simply aghast, and the wind tunnellers had felt that they were rather on the mat for having produced drag figures which were so much at variance. But a tremendous advance had been made since that time; the knowledge of transition points had thrown great light on the matter, and Professor Jones had placed it on a secure basis in his 1929 lecture on the streamlined aeroplane.

Finally, Mr. Irving made the suggestion that the paper by Miss Bradfield and Mr. Ellis might more appropriately have been entitled "The Use of Wind Tunnels in Aeroplane Design," rather than "The Use of Model Data in Aeroplane Design."

Mr. IRVING (*communicated*): The foregoing lift curves for R.A.F.34 and Clark Y.H. were originally plotted by Mr. Irving in connection with the question as to whether model rolling experiments could be relied upon to give truly comparative results as applied to the full scale at the stall. The answer seemed unavoidably to be in the negative.

Reverting to Mr. Fenton's point regarding pitching moment curves, however, an examination of all the lift-incidence curves (Figs. 9, 10 and 11) given by the data of the aforementioned R. & M. 1706 for six aerofoils indicates a general tendency for the full-scale curves to continue straight till closer on the stall than is the case with the model curves, in spite of differences in shape beyond the stall. It then seems a legitimate inference that the pitching moment curves will exhibit a similar tendency.

Mrs. AUBREY BURKE (*Companion*): She was intimately connected with the manufacture of scale models, and, referring to the title of the paper, pointed out that apart from the particular application dealt with, there were many other fields in which models were employed to produce data for aeroplane design. Notably were the experiments in tanks on model hulls and floats, assisting in flying boat design and the study, on models, of the questions of defence and attack connected with military aircraft design. She said that there was a device now which could be made applicable to any particular model so that the arc of fire of that type could be seen at a glance.

Discussing the manufacture of models, Mrs. Burke asked if any material had been found especially suitable for models used in wind tunnel tests. She suggested that according to the nature of the experiment, either mahogany coated with shellac varnish or metal, cast or made from the solid, would be the most practicable.

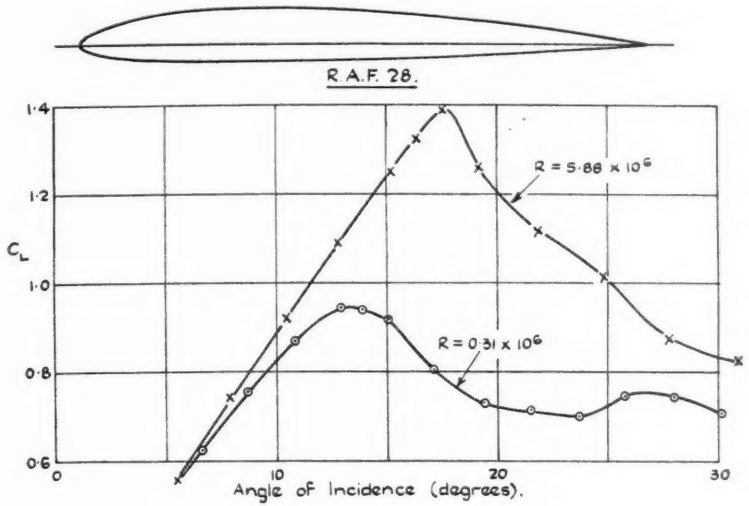
Finally she asked what was the greatest wind velocity achieved in tunnel experiments in this Country as she understood that at Langley Field a velocity of 500 m.p.h. had been reached.

Mr. ELLIS: Mahogany was certainly the best material to use for models of the sort tested in the type of tunnels discussed in the paper, *e.g.*, the 10ft. tunnel; but for some purposes large partial models could be made quite conveniently and accurately in soft wood. Very occasionally it was necessary to make quite large parts of a model in metal.

A SPEAKER said he believed the maximum speed of the high speed tunnel at the N.P.L. was about 600 m.p.h.—very near the velocity of sound.

On the motion of the CHAIRMAN, a hearty vote of thanks was accorded the authors for their paper; and the Secretary was asked to send a telegram to Miss Bradfield, regretting her enforced absence, assuring her that the meeting had very much enjoyed the paper, and wishing her a speedy restoration to health.

Mr. J. F. FOSS (*contributed*): The Chairman commented on the fact that the speeds of wind tunnels have not kept pace with those of flight, and, as Mr. Ellis did not refer to this point in his reply, he would like to mention the matter again.



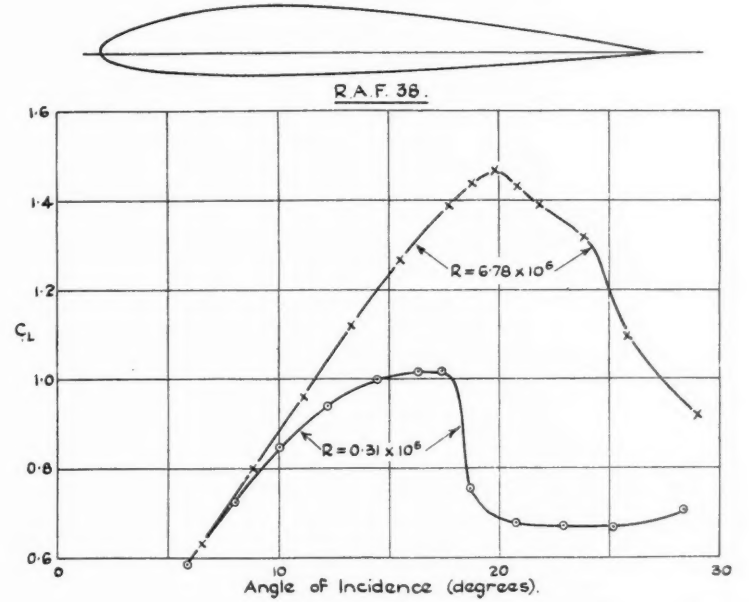




FIG. 10.

*Compressed air tunnel lift curves for R.A.F. 28 and R.A.F. 38 sections.*

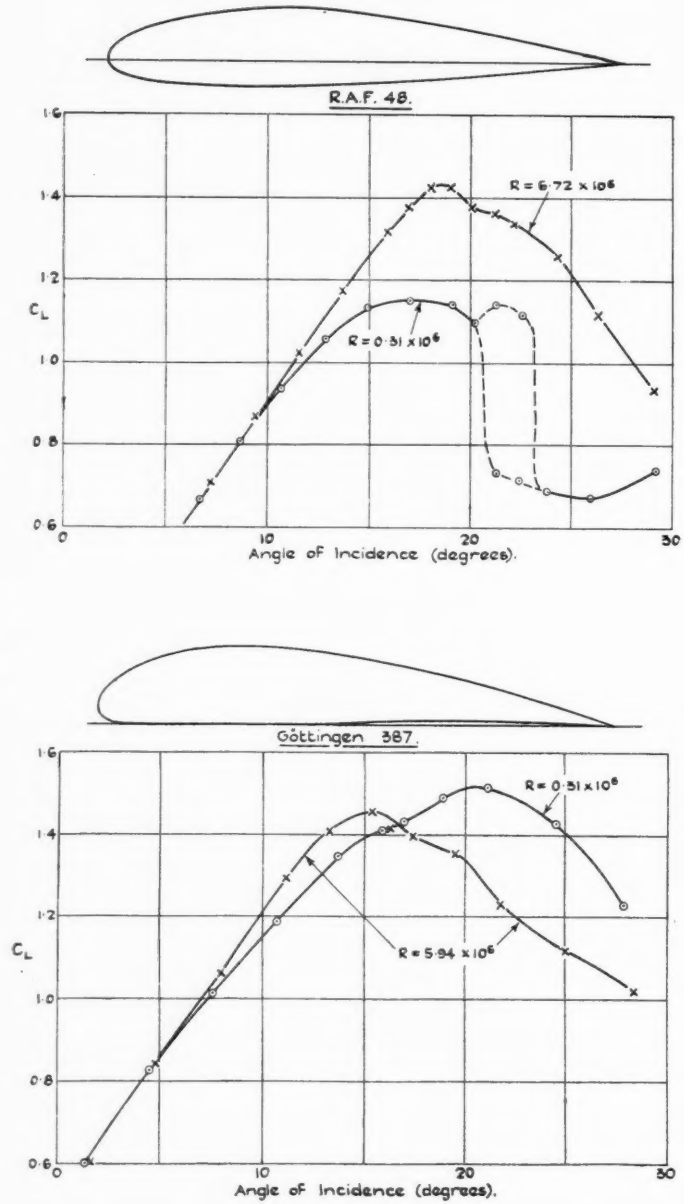



FIG. 11.

*Compressed air tunnel lift curves for R.A.F. 48 and Göttingen 387 sections.*

He would be glad to have the lecturers' opinion(s) as to the ratios of tunnel speeds to tunnel sizes which they consider necessary for various types of test.

It seemed to him that, for instance, a speed of 200ft./sec. in 4ft. tunnel is too high for the accuracy which it is possible to obtain with such small models. The higher the speed the more substantial the model supports and the greater the tare drag in proportion to that of the model. The accuracy of measurement of small changes in the model (the most frequent of manufacturers' tests) might even be reduced instead of increased by the higher Reynolds number obtained.

There is another aspect of this question, namely that one obtains the greatest Reynolds number for a given power with large cross sections and moderate speeds. He would like to know the minimum speed which in the lecturers' opinion is satisfactory for comparative drag tests in the minimum drag attitude. May it not be that drag measurements at a range of tunnel speeds to establish scale effects are now unnecessary, at least in manufacturers' tunnels, once the results from that tunnel have been lined up with C.A.T. or possibly V.D.T. measurements.

The mention of these two tunnels raises the question of turbulence, and hence of the difference of turbulence between one tunnel and another.

Mr. Relf, in his lecture before the Society last year, discounted the American theory of the effective Reynolds number (based on relative turbulence) at least in relation to minimum drag coefficients. He had noticed a disinclination among some other A.R.C. research workers to accept results from N.A.C.A. tests and a desire to repeat the whole test here before accepting the figures, and he would like to know whether this is in any way due to uncertainty about tunnel turbulence. If so, as a user of model data, he suggested that if the N.A.C.A. correlation of turbulence among their various tunnels is thought to be in error, steps should be taken to correlate results from at least all A.R.C. tunnels, and to publish any correction factors appropriate to each tunnel for the benefit of the user.

FURTHER REPLY TO THE DISCUSSION BY MISS F. B. BRADFIELD (*communicated*).

He would like to add a few comments on the discussion. The main point which has been brought up in several ways is the old question of how far we can measure drag in a wind tunnel and there he definitely agreed with Mr. Pierson that for a clean aeroplane, calculation on a skin friction basis is the foundation of the estimate. He did not think that putting up the tunnel speed by any practical amount to keep the proportionate flight and tunnel speed the same is of any use. What they do need is much more full-scale information as to the position of the transition point, since this is now becoming such an important variable. As regards Mr. North's point that, if he might put it that way, all reasonably streamlined shapes had the same drag at large Reynolds numbers, but that some were more " stable " than others, he wondered if this is another " transition " story. With a turbulent boundary layer the drags may be the same, but the ease with which the transition may be pushed back by polishing (or moved forward by roughness or excrescences) may vary. This is a fascinating subject, but it can only be studied in non-turbulent air, so that flight tests or a specially designed tunnel are essential.

On a point raised by Mr. Knowler, he had not met evidence of appreciable scale effect on $N_v$. The model tests are made with rudder fixed, and if the flight tests are with rudder free the stability may be different. If the rudder is horn balanced, the flight test would then be more stable rudder free; if the rudder is balanced by set back hinge it would be less stable. This is analogous to the changes in longitudinal stability stick fixed and free according to the type of elevator balance.

On Mr. Fenton's point as to kinks in pitching moments, he would say that a kink in the pitching moment of the model without tail plane comes from the wing characteristics and that a calculated correction can be made if the lift curve is known at large Reynolds number. But any kink appearing only when

the tail plane is present is probably due to an interference, and is likely to occur at the same incidence full scale.

In reply to Mr. Foss, the minimum Reynolds number for satisfactory comparative drag tests is that at which the transition point can be brought forward of the region in which the variations on the model are to be made. On a complete model with liquid-cooled twin engines and radiators, the transition on the nacelles can be brought forward by a string if the Reynolds number is about $1.5 \times 10^6$, *i.e.*, about 160-170ft./sec. for a complete model in a 10ft. tunnel.

*The 642nd Lecture read before the Royal Aeronautical Society since its foundation on January 12th, 1866.*

## PROCEEDINGS.

At a meeting of the Society, held in the rooms of the Institution of Mechanical Engineers, at Storey's Gate, St. James's Park, London, S.W.1, on Thursday, January 19th, 1939, a paper on " Some Corrosion Problems Relating to Modern Aircraft," by Mr. A. J. Sidery, Assoc. Met. (Sheff.), A.F.R.Ae.S., and Mr. J. W. W. Willstrop, B.Sc., A.I.C., was read and discussed.

In the chair: Mr. D. R. Pye, C.B., F.R.S. (*Fellow*) (Director of Scientific Research, Air Ministry).

The CHAIRMAN: Man's concern over the corruption of the materials he used was as old as history, or at any rate as old as the Bible, and it extended throughout the whole of engineering. But it assumed a peculiar importance in connection with aircraft structures, because whereas in some branches of engineering one could cover up the danger arising from corrosion with a comfortable factor of safety, for those in the aeronautical world conditions were more exacting! The danger must be prevented at the start, because inspection conditions in service were often peculiarly difficult.

During the last ten years the corrosion problem had assumed a totally different aspect from that assumed formerly. During the war period, and for some time afterwards, aeronautical people were concerned with the deterioration of dopes and glues. Nowadays they were concerned with the much more subtle dangers in metals, because the early stages of corrosion and the loss of strength due to corrosion might commence unperceived. There was special difficulty in dealing with corrosion because all the experiments had to be made in the laboratory, and in order to obtain results within reasonable time the corrosion must be accelerated. One was faced, therefore, with the difficult problem of correlating the conditions of experiment with the conditions in actual service. Laboratory experiments would be described by the authors of the paper, and he hoped the discussion would deal with conditions under which corrosion was of importance in service, and that suggestions would be made as to how those conditions could be dealt with in the laboratory. He felt that there was a danger sometimes for laboratory test conditions to be made unduly severe. On the other hand, one could never afford to take risks in that work, and the peculiar difficulty of the problem was to draw a proper balance between the ensurance of safety and the placing of too great a restriction on the freedom of the designer.

Introducing the authors, the Chairman said that Mr. Sidery had taken his diploma in metallurgy at Sheffield University, and after having served in the war he had joined the staff of the Royal Aircraft Establishment in 1923, where he had since served as a Scientific Officer on the staff of the Metallurgy Department. Mr. Willstrop had taken his degree at Birmingham University. Between 1915 and 1922 he had served the Royal Aircraft Establishment as a chemist, and was subsequently transferred to the Metallurgy Department, in which he had been working with Mr. Sidery.

# SOME CORROSION PROBLEMS RELATING TO MODERN AIRCRAFT.

By A. J. SIDERY, Assoc. Met. (Sheff.), A.F.R.Ae.S.,
and
J. W. W. WILLSTROP, B.Sc., A.I.C.

## EFFECT OF HEAT TREATMENT ON THE CORROSION-RESISTANCE OF ALUMINIUM ALLOYS.

It is well known that, under certain conditions, duralumin and other wrought aluminium alloys are liable to suffer intercrystalline attack, such corrosion being frequently accompanied by little visible corrosion product on the surface of the material. The necessity for careful temperature control during the solution heat treatment of duralumin and the beneficial influence of a rapid rate of cooling after such heat treatment on the corrosion-resistance of this material are now too widely appreciated to need emphasis here. It is observed that advantage, from the point of view of improved resistance to corrosion, is also gained in the case of wrought Y alloy and, to a smaller extent, in the case of wrought aluminium alloy to Specification D.T.D. 206 by cooling comparatively quickly after solution heat treatment. The best combination of corrosion-resistance and tensile strength observed by the authors in wrought Y alloy was obtained by quenching the material in cold water after solution heat treatment and ageing for two hours at 100°C. Wrought aluminium alloys of the type represented by Specification D.T.D. 206 require an " elevated temperature " ageing treatment for the development of the optimum tensile strength in the material, but in the fully heat-treated condition, are usually found to be susceptible to intercrystalline corrosion. The ageing of the solution heat-treated sheet at elevated temperature, as compared with ageing at ordinary temperature, increases the tendency of the material to corrode, irrespective of whether cold water or boiling water is used as the quenching medium in solution heat treatment. Quenching in cold water from the solution treatment temperature, as opposed to quenching in boiling water, results in the attainment of slightly better tensile strength and improved corrosion resistance in the material, even when finally aged at elevated temperature. Some values observed after exposure of some samples of D.T.D. 206 sheet to the sea water spray test* for one year are shown in Table I, which also includes corresponding values for unexposed samples.

TABLE I.

INFLUENCE OF VARIOUS HEAT TREATMENTS ON THE CORROSION-RESISTANCE OF 20 S.W.G. ALUMINIUM ALLOY SHEET OF COMPOSITION COMPLYING WITH SPECIFICATION D.T.D. 206.

| | Before Exposure. Treatment. | | | After Exposure. Treatment. | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| 0.1 per cent. proof stress, $T$/in.$^2$ | 21.1 | 20.5 | 13.1 | * | * | 13.7 |
| 0.5 per cent. proof stress, $T$/in.$^2$ | 23.8 | 23.4 | 15.1 | * | * | 15.5 |
| Maximum stress, $T$/in.$^2$ ... | 27.4 | 27.2 | 24.6 | 5.2 | 4.3 | 20.8 |
| Young's mod. $(E) \times 10^{-6}$, lb./in.$^2$ | 10.7 | 10.8 | 11.0 | 9.8 | 10.1 | 10.2 |
| Elongation per cent. on 2in. ... | 8.0 | 8.0 | 20.0 | 1.0 | 1.0 | 5.0 |

Treatment (1).—Solution heat treated at 525°C., quenched in cold water and immediately afterwards aged for 20 hours at 165-175°C.

Treatment (2).—As in (1), except that the material was quenched in boiling water.

Treatment (3).—Solution heat treated at 525°C., quenched in cold water and aged for ten days at ordinary temperature.

* Not obtainable.

* In the sea water spray test the specimens were suspended in the open air, but protected from rain, and were sprayed three times a day with natural sea water.

The mean values for loss per cent. in maximum stress after exposure test have been calculated from the figures given in Table I and are shown in Table II, together with figures of merit representing the relationship, as regards tensile strength after exposure, of samples in the three conditions of heat treatment.

TABLE II.

| Heat-treatment. | Loss % in maximum stress as compared with unexposed material similarly heat-treated. | Figure of merit in comparison with material showing best tensile properties after exposure. |
|---|---|---|
| Treatment (1)— | | |
| Quenched in cold water from 525°C. and aged for 20 hours at 165-175°C. ... ... ... | 81 | 25 |
| Treatment (2)— | | |
| Quenched in boiling water from 525°C. and aged for 20 hours at 165-175°C. ... ... ... | 84 | 21 |
| Treatment (3)— | | |
| Quenched in cold water from 525°C. and aged for 10 days at ordinary temperature ... | 15 | 100 |

The figures in Table II are not to be interpreted as a suggestion that the material should be put into service without elevated temperature ageing treatment, but are merely presented by way of indicating the price paid in intrinsic corrosion-resistance for the valuable improvement in tensile properties consequent upon the ageing of the material at elevated temperature.

### EFFECT OF RE-HEATING ON THE CORROSION PROPERTIES OF DURALUMIN.

The application to fully heat treated and aged duralumin of processes which necessitate re-heating the material may cause a serious reduction in its intrinsic corrosion resistance. It has been observed, for example, that when re-heated at temperatures above about 140°C., heat treated and aged duralumin is liable to become very susceptible to intercrystalline corrosion, whereas the re-heating of the material at temperatures up to about 125°C., whilst tending to increase its corrodibility as compared with that of material not re-heated, does not induce this propensity towards intercrystaline corrosion. It is desirable, therefore, that in cases where stove-enamelling treatments or other processes involving re-heating at elevated temperature have to be applied to duralumin, a temperature of 125°C. should not be exceeded. It is of interest to note that the corrosion resistance of duralumin which had been re-heated within the temperature range 50 to 170°C. does not appear to be affected either adversely or beneficially by subsequent storage of the re-heated material for 600 days at ordinary temperature.

### BEHAVIOUR OF ALUMINIUM ALLOYS UNDER STRESS/CORROSION CONDITIONS.

Serious consequences from the point of view of resistance to corrosion have followed the application of cold forming operations to certain finally heat treated and aged aluminium alloys. Fig. 1 shows an extruded T-section in an alloy of the type covered by B.S.S. L40 and gives an impression of the extent of the deformation to which the material had been subjected in the cold after final heat treatment and ageing. Such a section, after being bent, was exposed to the sea water spray test in the unprotected condition for a period of three weeks, at the end of which a series of cracks was observed along the concave edge of the web (Fig. 2) and away from the edge at the transitional region between bent and straight portions of the extrusion (Fig. 3). The cracking was observed to be intercrystalline and is illustrated in Fig. 4. No cracking occurred at the undeformed ends.

Similar cracking due to cold forming operations under unsuitable conditions has been observed in extruded material to Specification D.T.D. 363, an aluminium alloy which, when heat treated and aged, is capable of developing very high tensile strength. In this case the extrusion had been anodised after being formed and had been allowed to stand in the workshop for about two weeks, at the end of which the cracks shown in Figs. 5 and 6 were observed. The appearance of one of the cracks is shown in Fig. 7.

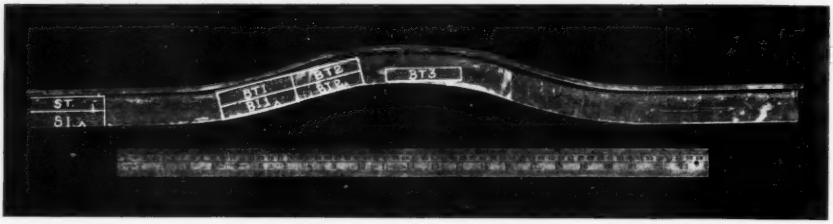


FIG. 1.

*Aluminium alloy extrusion to B.S.S. L40 formed cold after final heat treatment.*

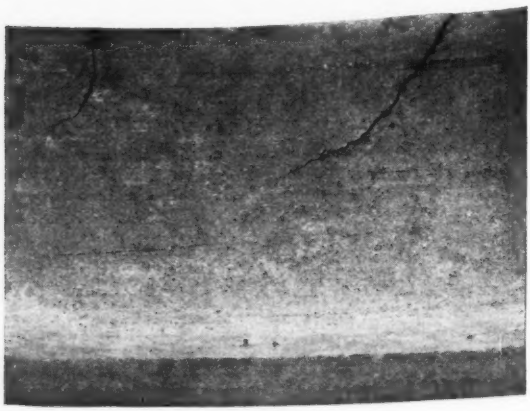


FIG. 2.

*Cracking in cold-formed aluminium alloy extrusion to B.S.S. L40 after exposure to the influence of sea water spray. Cracks at concave edge* ($\times 1\frac{1}{2}$).

The results of corrosion tests have indicated that this tendency to crack can be considerably reduced, if not entirely removed, by carrying out all forming operations preferably on annealed material and then applying the requisite solution and ageing treatments or, alternatively, by performing the shaping operations on solution heat-treated material and then applying the final "elevated temperature" ageing treatment.

It is usually observed that, under corrosive conditions with or without applied stress, high strength aluminium alloys requiring to be aged at elevated temperature for the development of their optimum tensile properties, are more resistant if exposed in the solution treated condition, *i.e.*, without elevated temperature

ageing treatment. It has been found, however, that under stress/corrosion conditions, alloys of the type corresponding to Specification D.T.D. 363 are more resistant when exposed in the fully heat-treated and aged condition than when exposed in the solution-treated condition.

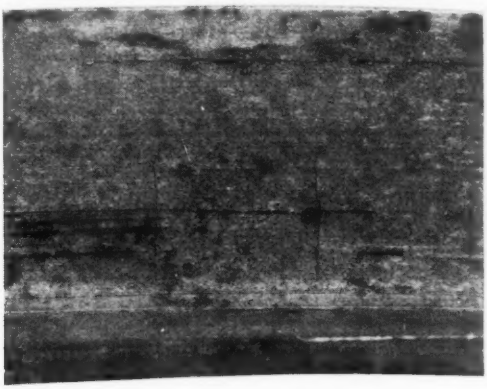


FIG. 3.
*Cracking in cold-formed aluminium alloy extrusion to B.S.S. L40 after exposure to the influence of sea water spray. Cracks near root of web* (× 1½).

FIG. 4.
*Intercrystalline corrosion in cold-formed aluminium alloy extrusion to B.S.S. L40* (× 100).

Correctly heat treated and aged duralumin shows comparatively high resistance to failure under stress/corrosion conditions.

Susceptibility to early failure has been observed in certain high strength steels, for example, nickel-chromium steel to B.S.S. T2 and high chromium low nickel stainless steel to Specification D.T.D. 168, when subjected to marine conditions under steady, but relatively low, tensile stress.

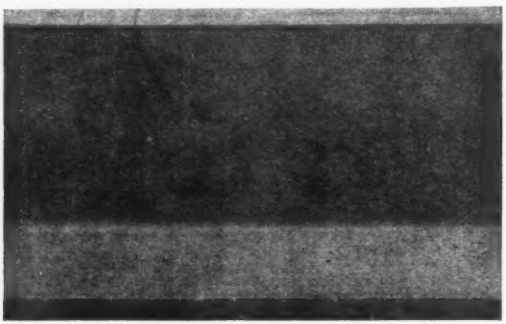


FIG. 5.

*Cracks in aluminium alloy extrusion to Spec. D.T.D. 363 cold-formed and anodised after final heat treatment.*

*Cracks in plain portion.*

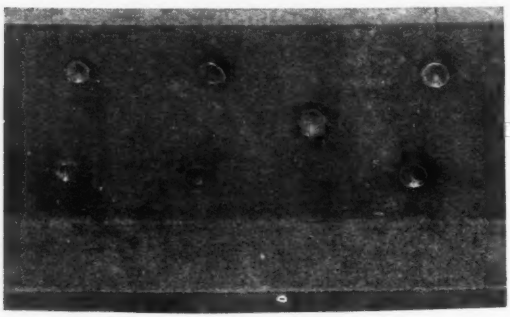


FIG. 6.

*Cracks in aluminium alloy extrusion to Spec. D.T.D. 363 cold-formed and anodised after final heat treatment.*

*Cracks at rivet holes.*

INFLUENCE OF FUELS ON METALS AND ALLOYS.

The subject of cold corrosion of engines by the products of combustion of fuels doped with tetraethyl lead has been ably discussed by Banks.* He described a protective preparation known as " E.G. 174," which had been developed for the protection during storage of engines which had been run on leaded fuel. This preparation consisted of a mixture of triethanolamine, butyl alcohol,

* F. R. Banks. Journal of the Institution of Petroleum Technologists, Vol. 23, No. 160, February, 1937.

aluminium stearate and lard oil and was intended to be injected into the engine cylinders by means of a special type of spray gun. In the same paper Banks referred to the corrosion of magnesium alloy fuel tanks by leaded fuels and to the work which had been carried out by the I.G. Farbenindustrie in Germany, the Ethyl Gasoline Corporation at Detroit and the R.A.E. at Farnborough on protection by the fitting of " cartridges " of corrosion-inhibiting substances at the lowermost part of the tanks. It is known that serious corrosion of magnesium alloys of the type corresponding to Specification D.T.D. 118 is liable to result from contact with leaded fuels in the presence of free water, the accumulation of a certain amount of which in the sumps of aircraft fuel tanks is difficult to avoid. These inhibitors, among which may be mentioned sodium or potassium fluoride, zinc chromate, calcium chromate, and potassium chromate, are soluble in water in varying degree and provide ions which exert a protective effect on the magnesium alloy.

FIG. 7.
*Intercrystalline cracking in D.T.D. 363 extrusion* (× 100).

In the absence of chromate treatment of the surface of the tank, comparatively poor protection is afforded by the use of sodium fluoride, but under these conditions potassium fluoride, zinc chromate and calcium chromate exert a very marked protective effect and appear to be somewhat superior to potassium chromate. Zinc chromate and calcium chromate possess an advantage over potassium fluoride on the score of their appreciably lower solubility in water and, in consequence, cartridges of the former salts require less frequent renewal and are much less liable to cause the formation of deposits in other parts of a fuel system by accidental transference of the solution from the fuel container.

All the various inhibitors mentioned are effective in preventing corrosion when fitted into chromate-treated tanks.

When zinc chromate is employed, it is very desirable that the material should not contain as impurities soluble salts other than chromates. Calcium chromate, when used as a corrosion inhibitor in magnesium alloy fuel containers, should be free from calcium hydroxide, otherwise solid crusts, consisting mainly of

calcium carbonate, are liable to form in the container and to give trouble in the fuel system.

Adequate protection against corrosion by leaded fuels containing free water is afforded to aluminium and the aluminium alloys normally used for aircraft tank construction by anodic treatment.

Fuels containing alcohols tend to cause corrosion of aluminium and aluminium alloys unless the latter are anodised. Stainless steels of the " plain chromium " and " two-score " types are slowly attacked by these fuels, which however, are substantially without influence on austenitic steels, 70/30 cupro-nickel, high-nickel nickel silver and even brass.

### Organic Protectives.

Temporary preservatives consisting essentially of solutions of wool fat, or anhydrous lanolin, have been in use for a number of years for the protection of raw materials and metal parts against corrosion during storage or during stages in manufacture. Quite a small amount of surface corrosion can, for example, affect adversely the bending properties of thin steel strip, tubes, etc., and adequate protection of these materials or finished parts made from them is essential. The application of lanolin to anodised aluminium and aluminium alloys as a supplementary protective is, of course, well known.

By the incorporation of a material such as zinc or barium chromate in the lanolin preparation, the protective effect of the latter is considerably increased. The coloration due to the addition of either of these chromates is of some service, incidentally, as a guide to the operator in the coating of large surfaces.

The films provided by the use of these preparations, however, are soft, easily damaged and, by reason of their somewhat sticky nature, are liable to collect dirt and foreign matter, especially during warm weather.

What would appear to be an important advance in the field of organic protectives for use on aircraft is the introduction of resin or wax-hardened lanolin preparations containing a pigment. The solvent employed may consist of equal parts of white spirit and solvent naphtha, to which is added about 40 per cent. by weight of a 60-40 mixture of lanolin and resin or wax-hardening medium. A special zinc chromate pigment is introduced together with a small proportion of kaolin to prevent caking. Protectives of this type are showing considerable promise. They can be applied by brush or by spraying and provide a film which is reasonably tough and able to withstand handling. The films afford a high degree of protection. One of their advantages lies in the appreciable saving in weight which is permitted. The weight of the pigmented varnish or enamel coatings usually applied to an aircraft is of the order of 2 oz. per sq. yd. of surface area. The weight of the resin-hardened lanolin film is of the order of 0.6 oz. per sq. yd. On a large flying boat the weight of the normal varnish or enamel coating may exceed 400lb. and the use of the resin-hardened lanolin type of coating, especially as a supplement to anodic treatment, in the case of aluminium alloys, appears to be worthy of consideration. Algicides may be incorporated in the preparation. Films of the resin-hardened composition are readily removed by rubbing with a rag soaked in petrol or other solvent or by scrubbing with hot soapy water. It will be realised from this fact that the coating can be easily reconditioned at will.

The authors wish to make due acknowledgment of the work done at R.A.E. by Mr. Le Brocq on the cartridge method of protection of magnesium alloy tanks and of that done by Mr. Le Brocq and Dr. Mardles on preservatives of the pigmented lanolin type.

### Joints and Jointing Materials.

In such a complicated structure as a modern aircraft, contacts between dissimilar metals cannot be avoided completely. With the present practice of constructing flying boat hulls of light alloy throughout as opposed to making

the upper portion of light alloy and the lower portion in stainless steel, a potential source of trouble has been substantially removed. It has been amply demonstrated by Evans* that the effect of restricted access of oxygen to a particular part of a piece of metal is to make that part anodic with respect to the surrounding material. Corrosion tends to become concentrated at the relatively inaccessible area when the piece of metal is subjected to corrosive conditions. Where riveted joints occur in light alloy structures, even between similar metals or alloys, corrosion may occur, under conditions of exposure to the influence of sea water spray, unless a suitable jointing medium is applied between the adjacent surfaces before assembly to exclude moisture. A jointing compound which has given very good results in joints between sheets of anodised duralumin or alclad and between anodised duralumin or alclad and 18-2 or 18-8 chromium-nickel stainless steels consists of a long oil paste or paint pigmented with barium chromate. It is obvious that in certain cases, such as, for example, the fixing of stainless steel end fittings into aluminium alloy tubes where the clearance is very small, difficulty will be experienced in maintaining an adequate layer of the jointing compound. In such cases careful consideration should be given to the choice or treatment of materials in order to avoid, if practicable, a high potential difference between adjacent parts or components.

Although it is desirable to eliminate contacts between copper-rich alloys and aluminium alloys as much as possible, occasions do arise which necessitate joints between these materials in an aircraft, *e.g.*, electrical bonding in connection with radio equipment. For such purposes it is necessary to remove any anodic film from the aluminium alloy at the point concerned in order to secure good electrical contact. Bonding clips and other similar fittings should, after being fitted, be treated with a suitable protective to exclude moisture. Organic protectives are normally employed for this purpose. A high degree of protection appears to be afforded, however, under conditions of marine exposure, by the application of sprayed coatings of metallic aluminium over joints between duralumin and copper.

### Riveted Joints.

Considerable progress has been made in the direction of reducing corrosion at riveted joints in the aluminium alloy plating of flying boat hulls, floats, etc. It is found that, by using aluminium-clad sheet and anodised duralumin rivets, a high degree of immunity from loss of mechanical strength of the structure due to corrosion is obtained, the well known protective effect of the aluminium coating of the sheet material extending to the duralumin rivets.

An alloy containing nominally about 45 per cent. of nickel, 23 per cent. of zinc and 30 per cent. of copper, corresponding to Specification D.T.D. 268, appears to be capable of useful application as a rivet material for stainless steels of the high chromium low nickel type, riveted joints made with this combination of materials exhibiting high resistance to corrosion by sea water.

The provision of a satisfactory rivet material for magnesium rich alloys still presents a problem of considerable difficulty from the point of view of corrosion.

### Radiator Corrosion Problems.

Of the wide variety of corrosion problems affecting aircraft, those relating to radiators form an important section.

Instances of corrosion of water radiators made of brass, both during storage and in service, have occurred from time to time and in many cases the failures have been attributable to the presence of zinc chloride in the radiator due to incomplete removal of soldering flux after manufacture. Washing out all traces of flux with hot water is not so simple a matter as it might at first appear. Small solid deposits of zinc chloride may be left on the tubes and when flushed with

* U. R. Evans. "Metallic corrosion, passivity and protection," p. 167 *et seq.*

water a layer of insoluble zinc oxychloride tends to form on the surface of the deposit. This hinders or may even prevent solution of the zinc chloride underneath.

This difficulty can be largely overcome by using very weak acid for flushing instead of plain water. Tests carried out at R.A.E. showed that a warm one per cent. solution of hydrochloric acid was considerably more effective than water for washing out flux residues, and that its effect on brass and solder was insignificant. For example, strips of four square inches surface area showed the following losses in weight after immersion for one hour in one per cent. hydrochloric acid at 60°C.

| | |
|---|---|
| Brass radiator tubing ... ... ... | Nil. |
| Brass coated with tinman's solder ... | 0.008 gram. |

Alternatives to Zinc Chloride Fluxes.

With a view to reducing corrosion troubles by avoiding the use of zinc chloride, several possible alternative fluxes have been tried and promising results have been obtained with a solution of 10 per cent. by volume of phosphoric acid in either methyl alcohol (commercial wood naphtha) or ethyl alcohol (methylated spirit). The behaviour of this flux in dip-soldering a nest of tubes is very different from that of a zinc chloride solution. When the fluxed tubes are dipped into molten solder the volatile alcohol forms a cushion of vapour between the solder and the tubes and spattering of flux or solder is considerably less than that occurring with an aqueous solution of zinc chloride. The fluxing properties of the alcoholic phosphoric acid flux compare favourably with those of zinc chloride solution and a nest of tubes can be satisfactorily dip-soldered without previous degreasing of the tubes.

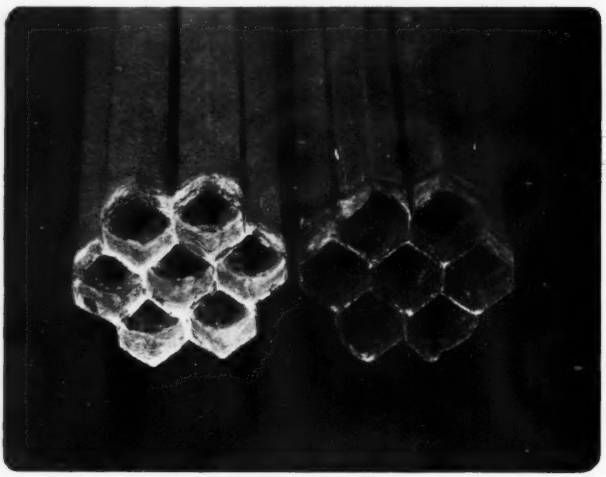


Fig. 8.

*Nests of radiator tubes soldered with zinc chloride flux (left) and alcoholic phosphoric acid solution (right) after one year's exposure.*

The corrosive effect of this flux was investigated by exposing an unwashed nest of soldered brass radiator tubes out of doors for 12 months in a glazed frame, open to the air but protecting the samples from rain. Protection from rain precluded the possibility of any residual flux being washed away during exposure. Subsequent examination showed only a small amount of corrosion product on the tubes and no apparent corrosion of the solder. An unwashed nest of tubes soldered

with zinc chloride flux (Specification D.T.D. 81) exposed for the same period was found to have suffered considerable corrosion both of the solder and the tubes.

The corrosion resulting from a residue of phosphoric acid is limited by the amount of phosphoric acid present, since all the damage the acid can do is to combine with an equivalent weight of the surrounding metal to form insoluble and, therefore, inactive phosphates. With a residue of zinc chloride on the other hand the resulting corrosion does not affect removal of the soluble chlorides and corrosion is liable to continue indefinitely.

Photographs taken after exposure of the nests of tubes soldered with zinc chloride (left) and alcoholic phosphoric acid solution (right) are shown in Fig. 8.

### Corrosion in Glycol-Filled Radiators.

The operation of liquid-cooled engines at higher temperatures with ethylene glycol as the cooling medium introduces further corrosion problems. At a temperature of about 130°C., the desired working temperature of the coolant, commercial grades of ethylene glycol were found to have an appreciable corrosive action on most metals and alloys including such normally resistant materials as silver and stainless steel. Apart from weakening the structure of a cooling system, another effect of corrosion was the formation in the glycol of a suspension or sludge which impeded circulation of the coolant.

Of the materials used in the construction of a normal cooling system, it was found that tinman's solder was most subject to corrosive attack by hot ethylene glycol. Furthermore, the melting point of the alloy is approximately 185°C. and its mechanical strength at the higher working temperature of a glycol-cooled system might be expected to be much less than at 100°C. Actual tests of the shear strength of lapped joints in brass sheet soldered with tinman's solder (B.S. Specification Grade B) gave values at 150°C., which were about half those at 100°C. For these reasons the need was felt for an alternative to tinman's solder which would have a higher mechanical strength at working temperature and also a greater resistance to attack by glycol.

### Strength Tests of Solders.

Shear strength determinations at ordinary temperatures and at 150°C. were made on lapped joints in brass and cupro-nickel for which various solders were used. Joints soldered with pure tin (M.Pt. 232°C.) or eutectic zinc-cadmium alloy (M.Pt. about 268°C.) showed superior strength at higher temperatures when compared with joints soldered with tinman's solder, but the resistance of either tin or zinc-cadmium solder to corrosion by hot glycol was no better than that of tinman's solder.

More promising results were obtained with silver-lead alloys containing 2.5 or 5 per cent. of silver. An alloy containing 2.5 per cent. of silver and 97.5 per cent. of lead forms a eutectic mixture melting at 305°C. Although the melting point is much higher than that of tinman's solder, it is possible to solder with this alloy using an ordinary zinc chloride flux solution. Silver-lead solder is corroded by hot glycol, but to a lesser degree than tinman's solder. Although weaker at ordinary temperatures, its shear strength at 150°C. is greater than that of tinman's solder at the same temperature.

Unfortunately there is more difficulty in " tinning " a metallic surface with silver-lead solder than with tinman's solder. This, as well as the higher melting point, renders more difficult the carrying out of repairs to radiators assembled with silver-lead solder.

### Reduction of Glycol Corrosion by Inhibitors.

Corrosion in aqueous solutions can be very much reduced and in some cases eliminated by the addition of soluble chromates to the solution. In the case of ethylene glycol such procedure is impracticable owing to chemical action between

the chromate and glycol. The possibility of using phosphates as inhibitors was more feasible. The phosphates of sodium and potassium, though soluble in water, are practically insoluble in ethylene glycol and cannot, therefore, be used. Phosphates of organic bases are more easily soluble in glycol, but in order that the phosphate shall be effective it is necessary first that the base be a strong one, otherwise its phosphate would have an acid reaction; secondly, that it be reasonably stable and non-volatile at the desired working temperature.

Triethanolamine fulfils these requirements. In its commercial form it is a colourless, viscous liquid miscible with water or glycol. It was found by trial that a neutral phosphate or mixture of phosphates was produced by mixing 10 parts by volume of triethanolamine with three parts by volume of phosphoric acid. The phosphoric acid used was the concentrated acid having a specific gravity of 1.75 and containing 90 per cent. of orthophosphoric acid. Comparative corrosion tests were made in the laboratory using plain glycol and glycol to which had been added 2 per cent. by volume of triethanolamine and 0.6 per cent. by volume of phosphoric acid. Strips of radiator tube brass were coated on both sides with various solders and immersed in treated and untreated glycol which was heated to 130°C. continuously for a period of 120 hours. The specimens were then examined for corrosion. In nearly every case the products of corrosion were readily removed by rinsing in water, so that a measure of the extent of corrosion that had occurred was obtainable from the loss in weight of the specimen.

The tests were carried out in test-tubes heated by means of a glycol bath. Preliminary trials showed that the degree of corrosion was greater when the tubes were left open than when they were closed by means of glass bulbs. It was evident, therefore, that corrosion was to some extent dependent on air dissolved by the glycol, and it was necessary to standardise conditions if comparable results were to be obtained. Subsequent tests were carried out in test tubes partially covered by glass bulbs, and complete sealing was avoided by interposing a bent piece of glass rod between the bulb and the test tube. In this way a moderate access of air was permitted while the effect of draughts was minimised.

The results obtained showed that the addition of triethanolamine phosphate considerably reduced the extent of corrosion, particularly that of the silver-lead alloys, as shown in Table III.

TABLE III.

CORROSION OF SOLDERS BY UNTREATED AND TREATED GLYCOL AFTER 120 HOURS AT 130°C.

| Solder. | Loss in weight in mg. per sq. dm. Untreated. | Treated. |
|---|---|---|
| Grade B tinman's ... ... ... | 225 | 70 |
| 20 per cent. tin, 80 per cent. lead ... | 240 | 67 |
| 10 per cent. tin, 90 per cent. lead ... | 125 | 40 |
| 2.5 per cent. silver, 97.5 per cent. lead ... | 108 | 1.5 |
| 5 per cent. silver, 95 per cent. lead ... | 89 | 2 |
| 2.5 per cent. silver, 1 per cent. cadmium, 96.5 per cent. lead ... ... ... | 60 | 1.5 |

Similar tests made with other materials which might form part of a cooling system showed that treatment of the glycol with triethanolamine phosphate effectively reduced its corrosive action on most metals and alloys, with the exception of zinc and magnesium.

In untreated glycol brass was found to suffer attack by "dezincification." In this type of corrosion the zinc appears to be dissolved away in preference to the copper, which remains as a spongy layer on the surface of the brass. That dezincification of brass is affected by stresses in the metal is shown by the following test in which specimens of stressed brass were subjected to the action of untreated

and treated glycol. Strips of brass sheet were bent at the middle to form a U and the limbs bound together with copper wire. Three of these were immersed respectively in pure glycol, commercial glycol and commercial glycol treated with triethanolamine phosphate. The temperature was maintained at 130°C. for 120 hours, after which the specimens were examined.

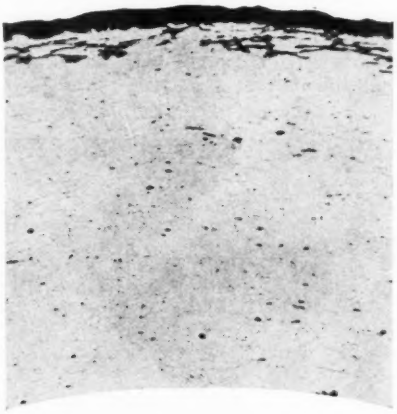


FIG. 9.

*Section of stressed brass after immersion for 120 hours in untreated glycol at 130°C. (× 100).*

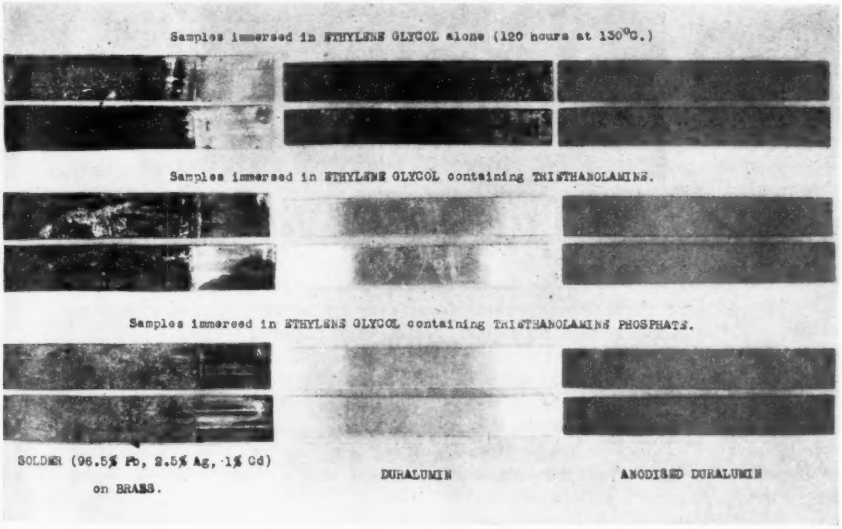

Samples immersed in ETHYLENE GLYCOL alone (120 hours at 130°C.)
Samples immersed in ETHYLENE GLYCOL containing TRIETHANOLAMINE.
Samples immersed in ETHYLENE GLYCOL containing TRIETHANOLAMINE PHOSPHATE.
SOLDER (96.5% Pb, 2.5% Ag, 1% Cd) on BRASS.
DURALUMIN
ANODISED DURALUMIN

FIG. 10.

*Various materials after immersion in glycol with and without inhibitors for 120 hours at 130°C.*

The specimen immersed in untreated commercial glycol showed an appreciable amount of dezincification on the convex surface of the bent portion, but none on the concave surface. A photomicrograph of a section of the stressed portion of the strip immersed in commercial glycol is shown in Fig. 9. In this photograph the copper appears black. Examination of an unstressed portion of the same specimen showed dezincification at both surfaces. The attack was not, however, as severe as it was at the bend. A very slight amount of dezincification had occurred on the specimen immersed in pure glycol, but none was found on that immersed in treated glycol. From the above tests it would appear that where stressed brass components are in contact with hot untreated glycol accelerated corrosion of parts in tension may be expected.

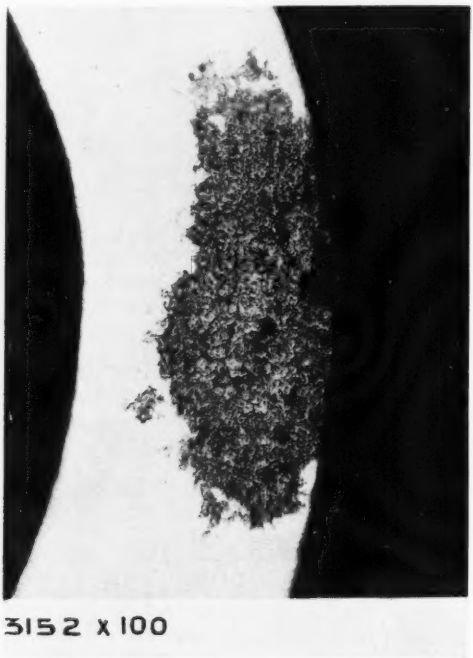



FIG. 11.
*Section of brass header tank from aircraft after 100 hours' flying with untreated glycol as cooling medium* (× 100).

Cupro-nickel appeared to be rather less corrodible by glycol than brass. Copper, however, was more seriously corroded by untreated glycol than either brass or cupro-nickel. In treated glycol the corrosion of copper was small. Tests with copper covered with oxide scale showed that in treated glycol the oxide was reduced to metallic copper, which became detached and was deposited in the form of a fine powder.

The aluminium alloys duralumin and MG7 were both corroded by untreated glycol to about the same extent. Duralumin was etched, leaving a blackened surface, and local pitting was observed. Anodic treatment of the duralumin appeared to afford little, if any, protection against attack by untreated glycol, and local pitting was as severe on the anodised as on unanodised samples. In treated

glycol corrosion was very much less and no pitting was observed. The appearance of duralumin and of samples of silver-cadmium-lead solder on brass after immersion in hot glycol, with and without inhibitors, is shown in Fig. 10.

With mild steel the corrosion in treated glycol, while only about one-fifth that in untreated glycol, was still undesirably high. Tests with plated samples showed that more satisfactory protection was afforded when the steel was nickel plated. Cadmium plating was less effective, while zinc plating was rapidly corroded in both treated and untreated glycol.

Corrosion-resisting steels in untreated glycol were corroded to nearly half the extent of mild steel. The corrosion in treated glycol was, however, quite small.

The relative corrosion of various materials in contact with treated and untreated glycol is given in Table IV.

TABLE IV.

CORROSION OF VARIOUS METALS AND ALLOYS BY UNTREATED AND TREATED GLYCOL AFTER 120 HOURS AT 130°C.

| Material. | Loss in weight in mg. per sq. dm. Untreated. | Treated. |
|---|---|---|
| Brass ... ... ... ... ... | 11 | 1.5 |
| Cupro nickel ... ... ... ... | 9 | 1 |
| Copper ... ... ... ... ... | 83 | 2 |
| Duralumin ... ... ... ... ... | 20 | 1.5 |
| Anodised duralumin ... ... ... ... | 28 | 1.5 |
| MG7 alloy ... ... ... ... ... | 23 | 1.5 |
| Mild steel (S.3) ... ... ... ... | 67 | 13 |
| Mild steel nickel plated ... ... ... | 33 | 3 |
| Mild steel cadmium plated ... ... ... | 37 | 6 |
| Mild steel zinc plated ... ... ... | — | 560 |
| Low nickel stainless steel (D.T.D. 60A) ... | 26 | 1.5 |
| Austenitic stainless steel (D.T.D. 166) ... | 27 | 1.5 |

FLIGHT TESTS WITH GLYCOL-COOLED ENGINES.

After flying tests at Farnborough totalling 100 hours using untreated ethylene glycol as the cooling medium, the radiator and header tank of an aircraft were removed and examined. The radiator shell, header tank and tubes were of brass and had been assembled with grade B tinman's solder.

Corrosion by dezincification had occurred on the interior surfaces of the header tank and, although complete penetration had not taken place, in many regions less than one-third of the original wall thickness of brass remained in sound condition. The radiator tubes had also been severely attacked and in places complete penetration had resulted.

Photomicrographs of sections of the header tank and one of the tubes are shown in Figs. 11 and 12 respectively.

The soldered joints had not been unduly attacked and the solder appeared to be in good condition generally and not to have suffered severe local attack by the glycol. Subsequent examination of the glycol taken from the radiator showed, however, that about 4½ ounces of solder had been lost by corrosion of the joints in the tank and radiator. It appeared probable, therefore, that the attack by the hot glycol had been uniformly distributed over the surface of the tinman's solder.

A sample of the glycol taken from the radiator was very turbid and contained in suspension a heavy sludge which, after being allowed to settle, occupied about 2 per cent. of the volume of the glycol. An analysis was made to determine the amounts of various metals present in the glycol. The results obtained are shown in Table V.

A second aircraft, in which treated glycol was used as the cooling liquid, was flown for periods totalling 400 hours. In this case the radiator was constructed

of cupro-nickel tubes in a brass case and was soldered with silver-lead solder. The glycol was afterwards examined and analysed for metallic contact. It was turbid in appearance, but only a small amount of grey sediment settled out after standing for a few days. This did not appear sufficient to impede circulation.

The result of the analysis is also given in Table V. In spite of the much longer flying period, the amount of metallic impurities in the glycol is little more than a quarter of that found in the untreated glycol from the first aircraft.

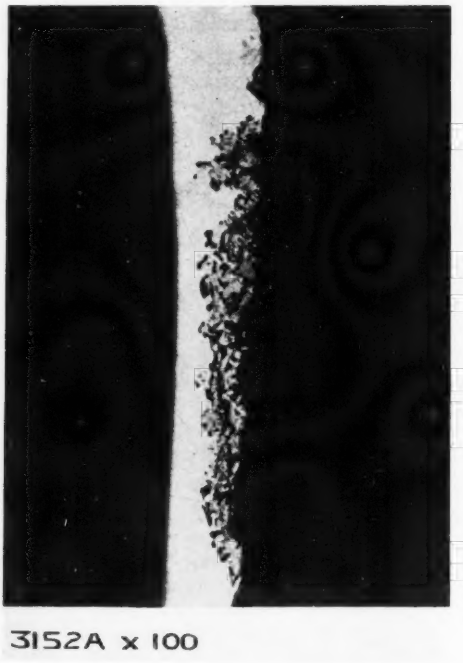



FIG. 12.

*Section of brass radiator tube after 100 hours' flying with untreated glycol as cooling medium* (× 100).

TABLE V.

METALLIC IMPURITIES IN GLYCOL AFTER FLIGHT TESTS.

| Aircraft | A | B |
|---|---|---|
| Total flying time | 100 hours | 400 hours |
| Cooling medium | Untreated glycol | Treated glycol |
| Metal content | gms./gall. | gms./gall. |
| Lead | 4.42 | 1.87 |
| Tin | 6.10 | Nil. |
| Copper | 0.65 | 1.41 |
| Aluminium | 0.97 | 0.14 |
| Iron | 0.18 | 0.06 |
| Zinc | 0.29 | 0.02 |
| Nickel | 0.18 | 0.08 |
| Total | 12.79 | 3.58 |

Of the metals present lead and copper are the chief constituents. The low value of the nickel content would indicate that no serious corrosion of the cupro-nickel tubes occurred and the presence of only a very small quantity of zinc shows that the attack of the brass radiator casing was small. The major part of the copper in the glycol presumably came from copper connecting tubes and much of it probably arose from solution of oxide film from the bore of the tubes.

The authors have attempted to draw attention to but a few features connected with the study of corrosion as applied to present-day aircraft and have deliberately refrained from touching upon such a subject as corrosion fatigue, for example, which is too wide to be within the scope of this paper.

In conclusion, the authors wish to acknowledge gratefully the valuable assistance rendered ungrudgingly by various colleagues at the Royal Aircraft Establishment during the preparation of the paper, and desire to express their thanks to the Director of Scientific Research, Air Ministry, for permitting publication.

## Illustrations.

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## Discussion.

The Chairman: The paper contained a great deal of information resulting from accurate observations, but he had not found in it much that was directed to principles. For example, in the first part of the paper it was stated that advantage was to be gained by cooling comparatively quickly after solution heat treatment; that ageing at 165-175°C., as compared with ageing at ordinary temperature, increased the tendency to corrode; that quenching in cold water from the solution treatment temperature resulted in slightly better tensile strength than quenching in boiling water, and so on. Those were, no doubt, important facts which we needed in practice. But he asked whether a serious attempt had been made to relate, for example, the facts about intercrystalline corrosion and how it was affected by different methods of processing, to the crystalline and molecular structure in the material. Scientific research should aim at achievement in two stages—firstly, ascertaining the facts and then finding the reasons for those facts. There was plenty of information in the paper about what happened, but very little about *why* it happened.

The Chairman asked whether it was always the case that when intercrystalline cracking occurred there had been in the material a residual stress at the place where the crack formed, and also what was meant by the term " long oil " used in the expression " long oil paste."

Mr. Sidery: Much information had been obtained by correlating the effects of variations of heat treatment on the corrosion behaviour of various light-alloys with the effects on the microstructure of the materials, but that information had not been included in the paper because it was desired to avoid overburdening the latter with a large amount of detail of that nature.

The term " long oil varnish " was a trade term applied to a varnish of which the greater part consisted of boiled linseed oil with an appropriate quantity of driers. Cheap varnishes were usually loaded with comparatively large additions of resins such as Kauri gum or copal, but the better grades of oil varnish usually came under the heading of " long oil varnishes." The expression " long oil paste " referred to a paste made by mixing a pigment, such as barium chromate, with a " long oil varnish." Residual stress in the material was not essential to the occurrence of intercrystalline corrosion. Intercrystalline corrosion had been observed many times in cases where no stress had been applied to the material.

Air Commodore R. H. VERNEY, C.B.E. (*Associate Fellow*): The paper was of great interest, but he was sure the authors appreciated, quite as much as anybody, that it gave an account of something which was always going on, and that they had only touched the fringe of a subject, many aspects of which still required a great deal of exploration.

A problem which interested most people concerned with aeroplane construction was whether we were not " over-gilding the lily " by putting paint on the top of Alclad. On the occasion of the lecture by Mr. T. E. P. Wright, dealing with American practice, some rather strong opinions had been expressed, which he personally had thought were not altogether justifiable. But there was an indication that in England we were insisting upon rather more drastic protection than was found to be necessary in America. One obvious answer which might have been made was that the American aeroplanes, except perhaps the Naval aeroplanes in the Panama Canal region, were operating in much better climates than our own. A large proportion of the Royal Air Force aeroplanes had to operate all over the world, as did also the large civil aeroplanes used on the Empire services.

From his own observations it seemed that the Americans paid more attention than we did in this country to the prevention of scratching of Alclad surfaces. Perhaps we regarded Alclad as something which would ultimately be painted, and, therefore, scratching it was not a very serious crime; but in America some very strong views were held concerning that problem. Mr. Wright had said that the Curtiss-Wright Corporation dipped all their sheets in a protective oil, known as Linol which had a tinge of Prussian blue, so that one could ensure that the sheets were covered. When an aeroplane was completed, the protective oil was cleaned off from the outside, whereas on the inside it remained to assist the Alclad. He believed that some other firms, including the Lockheed Company, actually went to the trouble of sticking sheets of brown paper on to the Alclad in order to prevent scratching; if any scratching occurred it could be detected at once, because the paper became torn. He asked whether, if we in this country devoted more care to the protection of Alclad against scratching, we could do with less drastic paint protection?

Another question was whether the new resin-hardened lanolin coating, which appeared to dry very nicely, according to samples exhibited at the meeting, could replace the sticky barium chromate paint which was used between surfaces in this country? A paint which dried so well would be much more popular than a sticky paint, because when a man picked up his riveting tools after having dealt with a sticky paint, everything seemed to be very messy.

The work done on the development of inhibitors of radiator corrosion had been very fine indeed; he did not think that glycol would have been used as a coolant without giving rise to very great trouble, but for the work on inhibitors at the R.A.E.

Probably the authors had refrained from discussing exhaust manifolds out of their desire to avoid overburdening the paper; but he would like to hear something about exhaust manifolds, because in the past they had presented serious problems in regard to corrosion.

Finally, he said that the user, after all, was entitled to call the tune, and therefore the Air Ministry was quite justified in calling for some proved method of protection, even if it were somewhat irksome. To emphasise that, he recalled that the Signal Squadron at Cranwell some six or seven years ago had had aeroplanes fitted with ordinary mild steel exhaust manifolds, and in order that the aeroplanes should not give the appearance of a dump of broken-down motor cars, it was the practice of the officers to buy black lead and to have the exhaust manifolds carefully cleaned and black-leaded after use. That had involved a considerable number of man hours of labour, apart from the expense to the officers! But the fact served to indicate that the user had the right to call the tune. Therefore, the Air Ministry must be regarded as justified in saying what it wanted.

Mr. SIDERY: Although undue scratching of Alclad should be avoided where possible, particularly in cases where thin gauges of metal were used, the thickness of the protective aluminium coating on which might be only of the order of one thousandth of an inch, the aluminium coating on Alclad was anodic with respect to the basic material and it exerted its protective effect even at cut edges, where the basic material would be exposed. Some variable results had been observed in corrosion tests on samples of aluminium-coated material from various sources. For example, some from the Continent had been definitely inferior to our home-produced materials. The degree of purity of the aluminium coating and, also, the conditions of manufacture, had a considerable influence on the corrosion behaviour of Alclad sheet.

With regard to the suggested use of the pigmented resin-hardened preparation in joints, he suggested that it was liable to become a little hard and that it was rather more desirable to use in joints a material which remained plastic.

Discussing the corrosion of exhaust manifolds, he said that certain corrosion-resisting steels had shown extraordinarily promising behaviour at Farnborough. Recently, a manifold made of such material had been examined after having been in use on an aircraft for a very considerable period—the number of flying hours was over 300, extending over approximately 1½ years, and the material was found to be in extraordinarily good condition. It appeared that the selection of a suitable stainless steel provided the answer to the problem.

Wing Commander A. F. SCROGGS (*Associate Fellow*): He commented that only a passing reference was made in the paper to the problem of the corrosion of engines and fuel tanks by leaded fuels, and he asked for some more information. The preparation known as " E.G. 174 " gave fairly effective protection against lead attack during storage of engines in those parts of the engines to which it could be applied. But that limited it to the inside of the cylinder; and as the lead also got into the lubricating oil, its effect might be felt to some extent in all parts of the engines. Further, the problem of protection during storage of engines, although a serious one, was not the only one connected with the use of leaded fuels. The effect of lead on some parts of an engine (notably the valves) during running was in some cases appalling; not only did it affect seriously the reliability of the engine if it were allowed to proceed, but it also affected the life of the engine between overhauls and the number of parts which had to be scrapped at times of overhaul.

Another matter on which he asked for information was the possibility of protecting the outside of the cylinders of air-cooled engines against corrosion, especially those which had to operate in hot and damp climates and those which occasionally had a bath in sea-water. He would be glad to know whether there was any hope of effective treatment to prevent corrosion in such circumstances.

Mr. SIDERY: He had seen examples of valves which had been faced with Stellite and which appeared to be in very good condition after an appreciable period of service. Cadmium plating was usually of service in protecting cylinder heads; he believed that the indifferent behaviour which had been observed occasionally was due to a great extent to faulty plating, arising from imperfect preparation.

Mr. S. G. E. NASH (*Associate Fellow*): Probably the contribution to the corrosion problem for which the aircraft engineer, as distinct from the metallurgist, was most grateful, was the publication of the potentials of the various metals in sea-water against the standard calomel electrode which allowed of easy assessment of the probability of corrosion. For that, he believed, thanks were due to Mr. Willstrop. A theory had been published by T. P. Hoar, M.A., in which it was stated that polarisation of the electrode metals, due to current density, might even increase the potentials of metals. The case of cadmium (of $-.402$) and iron ($-.44$) was cited, and it was stated that cadmium coatings were anodic towards iron. There was also the effect of differences in potential even between rough and smooth surfaces of the same piece of metal, and the effect of concentration between adjacent pieces of dissimilar metals.

Referring to the behaviour of RR. 77-D.T.D. 363, he said that since annealing was rarely practised, the usual procedure in the works was to normalise at 490°C. before working. Apart from the fact that annealing at 360°C. gave the minimum stresses, both proof and ultimate, and therefore greater ease of working, he asked whether the authors of the paper had noticed any difference in the corrosion properties, after annealing and after normalising respectively. Further, since the rate of cooling had rather an important effect on corrosion problems generally, he asked whether the practice of " super-annealing " or cooling slowly to about 200°C., and then quenching, produced any deleterious effects.

With regard to the statement that when duralumin was reheated up to 125°C. increased corrodibility had occurred, he asked whether that referred to the general surface attack and pitting.

It was of interest to note that both of the light alloys for which the corrosion characteristics had been described, *i.e.*, RR-56 sheets (D.T.D. 206) and D.T.D. 363 (RR. 77), were the most highly stressed materials available to the industry. He wondered whether there was a general scaling down of corrosion characteristics with the scaling down of the stress; for example, would one of the alloys of the L. 40 group be less liable to serious corrosion than, say, D.T.D. 363?

Finally, he asked if it were to be assumed in general that alloys with elevated temperature ageing were fundamentally more liable to intercrystalline attack than those aged at room temperature.

Mr. WILLSTROP: The published values of potentials of cadmium and mild steel in sea-water were determined under conditions in which there was no current flowing; so that the effect of polarisation did not arise. Generally speaking, mild steel was more " noble " than cadmium, and for that reason it was protected under normal circumstances by a layer of plated cadmium.

Mr. SIDERY: Dealing with the question concerning the forming of D.T.D. 363 materials, he said the authors had found that, from the corrosion point of view, it was rather better to carry out the forming of the high strength materials in the annealed condition, and to follow with the full solution treatment and ageing treatment. Obviously, a certain amount of distortion was liable to occur, and he suggested that some form of jigging during the heat treatment was desirable.

Mr. J. V. CONNOLLY (*Associate Fellow*): He was interested to note that, although a good deal of research had been conducted on the duralumin alloys, very little mention was made in the paper of the magnesium group, except in respect of corrosion in tanks. He pointed out, however, that quite a lot of major structures were being made of magnesium alloys—Elektron and so on—and that people were thinking of making important stressed parts in cast magnesium. He asked what corrosion properties one might expect in a fairly substantial magnesium alloy casting and what method of protection would be suitable for such a casting. In highly stressed parts it was sometimes necessary to use fittings in stainless steel or some other high strength material, to distribute concentrated loads, and he asked whether there was any likelihood of electrolytic corrosion arising between steel or other alloys and magnesium.

Alternating loads on most materials in even a slightly corrosive solution accentuated the corrosion fatigue; but he asked whether the same effect was noted if the material were stressed whilst an electrolytic action was going on which was not due to a surrounding electrolyte but to the potential set-up by the contact of dissimilar metals.

Mr. SIDERY: He referred Mr. Connolly to two very valuable papers presented to the Institute of Metals by Dr. H. Sutton and Mr. Le Brocq, in which they had dealt very thoroughly with methods of protecting magnesium alloys.

Where steels were in contact with magnesium alloys, the plating of the steels with zinc or cadmium was of some value in reducing corrosion of the magnesium alloy, though this procedure could be regarded only as a palliative. Under fairly severe conditions of exposure involving contact with a material such as steel,

corrosion of the magnesium alloy sooner or later was almost inevitable in view of its high chemical reactivity.

Mr. E. G. FISCHELES (*Associate Fellow*): He asked whether the spraying of pure aluminium on scratched aluminium clad alloys would afford adequate protection, because it seemed that by such means one could produce material somewhat similar to Alclad. Further, spraying had the advantage that it could be applied to all sizes of components in thin layers. Also, the process is satisfactorily used to prevent corrosion on exposed engine parts and accessories.

Mr. SIDERY: He agreed that the idea of spraying very pure aluminium on aluminium alloys was attractive, provided the sprayed coating was of adequate thickness. Sprayed coatings were likely to be rather porous, but there were distinct possibilities in the application of that method of protection to some of the aluminium-clad alloys in cases where the coating on the latter had been scratched seriously. It was well known, of course, that the coating of pure aluminium on Alclad sheet had a marked protective effect on cut edges.

Mr. R. H. CHAPLIN (*Associate Fellow*): Emphasising the importance of the development of the resin or wax-hardened pigmented lanolin preparations for the protection of aircraft structures, he agreed that the weight of the pigmented varnish or enamel coatings usually applied was of the order of 2oz. per sq. yard of surface area, and pointed out that, inasmuch as they were applied to both sides of a structure, they represented an additional weight of 4oz. per sq. yard; this was the weight when sprayed; when dipped, the weight was about 5 oz. per sq. yard, and the weight of the varnish or enamel applied represented something like 9 per cent. of the total weight of the material used. Quite a small fighter might carry 1oolbs. of paint—which was consistent with the authors' statement that the weight of the normal varnish or enamel coating on a large flying boat might exceed 4oolbs. That must mean a sacrifice of part of the load-carrying capacity of the aircraft, and he would like to have further information on the suitability of this type of resin-hardened lanolin preparation for permanent, or failing this, semi-permanent protective purposes.

Commenting on the picture of RR. 77, showing cracks commencing at rivet holes, he asked whether the part of the extrusion in which the cracks had occurred was bent, or whether the stress was induced solely by the swelling of the rivets; in other words, was the riveting of RR. 77 likely to give rise to intercrystalline corrosion?

Mr. SIDERY: At the moment he had no data concerning tests made with the resin- or wax-hardened and pigmented lanolin coatings on actual flying boats; but the coatings had much to recommend them, particularly in view of the ease with which they could be reconditioned.

The whole of the RR. 77 extrusion referred to was bent, and the rivets were fitted only at one end of the section. He did not think the cracking had any relation to the presence of the rivets or the rivet holes.

Dr. H. SUTTON (Royal Aircraft Establishment) (*Fellow*): He commented on the seeming paradox that whereas generally the corrosion resistance of metals decreased with increasing amounts of working, yet the pure aluminium coating on aluminium alloy sheets, which coating was much softer than the alloy core and presumably suffered more deformation during rolling than did the core, had a phenomenal resistance to corrosion. He had often wondered how the corrosion resistance of such aluminium-coated sheets compared with that of high purity aluminium sheets of similar thickness, and his own impression was that the coated sheets had a really greater resistance to the early onset of corrosion than had the sheets of high purity aluminium. He would like the views of others on that problem.

In connection with stress and corrosion, he considered that we in this country were rather fortunate that we had not to deal more with the magnesium-aluminium type of alloy, which, according to the published work of German investigators, was rather sensitive to stress-corrosion. That encouraged us to think more of

our old friends, the duralumin group of alloys, especially as experience was showing that the duralumin type of alloy was relatively highly resistant to failure under stress and in corrosion. It seemed to him that we appreciated the virtues of duralumin most when we tried to find a good substitute for it. Mr. Nash had made the veiled suggestion that higher tensile properties, and so on, were obtained at some expense; and it seemed that there was a good deal of truth in that. But certain it was that the recent German investigations by Althoff had shown that the duralumin type of alloy had greater resistance to stress and corrosion than had the aluminium magnesium type of alloy.

One very interesting feature of failure under stress in corrosion—and attention had been drawn to it by Mr. Grogan, at the National Physical Laboratory, Teddington—was the sensitivity of some alloys to atmospheric stress-corrosion. In other words, the laboratory atmosphere would lead to the corrosion of specially sensitive alloys under stress, and such susceptibility to stress-corrosion in certain conditions suggested that, as the Chairman had indicated, we needed to know more about the fundamental things relating to corrosion and failure.

With regard to fuel corrosion problems, he often felt that we in this country were fortunate in having aircraft fuels which were generally free from alcohol. Frankly he had been greatly surprised that some of the carburettors he had seen in the past had not corroded to bits, for there was a heterogeneous collection of metals in contact in the float chambers and other parts. He was very glad to note, however, that considerable improvement had been effected, and there was hope for the still further elimination of corrosion troubles if knowledge and common sense were used.

He did not know whether the authors would like to forecast the ideal radiator material of the future; and he had a suspicion that they would ask him what would be the ideal coolant in the future.

However, the paper illustrated that a great deal could be done to mitigate the worst effects of corrosion by the careful interpretation of the results of laboratory experiments.

Mr. E. HOLGATE: He asked whether the pigmented lanolin protective coatings were to be regarded as permanent or only temporary coatings, inasmuch as it was stated in the paper that they were readily removed by rubbing with a rag soaked in petrol or other solvent or by scrubbing with hot soapy water. Presumably the ability to remove the coatings readily was of advantage if they were temporary coatings, but was a disadvantage if the coatings were regarded as permanent.

Mr. SIDERY: The resin-hardened pigmented lanolin preparation was to be regarded more as a temporary protective, inasmuch as the coating could be very readily removed. It was not proposed that it should take the place of paint completely, particularly where conditions were such as to involve a large amount of abrasion, although, even if the preparation were used under these conditions, any damage caused to the protective film could, in a large number of cases, be repaired quickly in the normal maintenance of the aircraft.

Mr. N. D. NEW (*Associate Fellow*): Discussing the corrosion protection of bolts in wood, he said it had been the practice in the past to fill the holes with temporary rust preventatives in places where bolts were subject to severe corrosion, and he asked whether the authors would recommend the use of the barium chromate preparation in place of the old rust preventative, and whether the barium chromate preparation might possibly affect the bearing strength of the wood or whether it would harm the wood.

Mr. SIDERY: The use of the barium chromate lanolin preparation in holes through which steel bolts passed was certainly to be recommended in preference to the plain lanolin.

He had no actual data as to the effect of the barium chromate addition upon the wood, but he was of the opinion that it was unlikely to affect the wood adversely.

Mr. M. S. FELTHAM ROBERTSON: He asked for information concerning the behaviour of D.T.D. 318, a bronze for radiator tubes, known by the trade name of "Barronia." It was claimed to be better than cupro-nickel.

Mr. WILLSTROP: He was not aware of any tests made on the alloy mentioned. Tests had been made on "Tungum" (an alloy containing about 12 per cent. zinc and a few per cent. of aluminium), and on "Gilding Alloy" (containing 97 per cent. copper and 3 per cent. zinc), as radiator tube materials, and both appeared to be rather more resistant than brass.

Captain J. LAURENCE PRITCHARD (*Hon. Fellow*) (Secretary of the Society): What puzzled him was that neither in the paper nor in the discussion had there been any attempt to deal with the fundamental causes of corrosion in particular materials and to find out exactly what corrosion was and what it did. There was in existence a stainless silver, which he supposed was a material which did not corrode easily. He asked whether any fundamental steps were being taken to show how the various materials used in aircraft, which included metals and alloys and materials such as bakelite—which latter, he supposed, did not corrode—could be applied in association in such a way as to avoid corrosion either by acids, oxygen or intercrystalline. It seemed to him that a considerable amount of time and money was spent in reducing the incidence of corrosion, though without preventing it completely; and then, in order to ensure that corrosion would be reduced, a weight of 400lbs. of paint was applied to a flying boat. One would have thought it possible, after all the work that had been done on corrosion problems, to dispense with that weight of paint and to enable a flying boat to carry the extra 400lbs. of paying load.

Dr. H. SUTTON: He assured Captain Pritchard that researchers in this country were working hard on the fundamental problem as to why particular metals corroded, whereas others did not. He believed it was true to say, however, that the corrosion-resisting steels were not arrived at by inductive treatment, but as the result of passing observation, though a very valuable observation. It was common knowledge among corrosion specialists that Dr. U. R. Evans, at Cambridge, had isolated the very thin film of oxides which afforded remarkable protection to stainless steels. There were many aeronautical engineers in this country who were very much impressed by the service experience gained with the corrosion-resisting steel components used in British aircraft.

With regard to silver, a very fine contribution had been made by Dr. U. R. Evans, Mr. Price and Mr. Thomas, at Cambridge, who had produced on silver a film which rendered it resistant to tarnishing. That was an example of the success of inductive treatment. By theoretical treatment they had worked out the kind of film they wanted and had set about producing it in the laboratory. He felt sure that light metals would eventually respond to similar treatment, if the study of the problem in relation to those metals was pursued in a like manner.

Mr. T. H. TURNER (*Associate*): Discussing the fundamental reason for corrosion, he pointed out that in nature our metals were combined with other elements, and although we had divorced them by furnace treatment, the natural affinity of one for the other had not been altered, and sooner or later they would revert to the combined state. In the corrosion-resisting metals the reversion to the combined state was hindered by the compound formed, and it was believed that in the stainless steels that compound was formed so instantaneously and so uniformly all over the surface that, although the metal wanted to corrode, it could not. Its discovery was an accident, and it could be said that the discovery of duralumin was an accident, arising from observation of existing material. He suggested that we should never find a panacea for all corrosion; there could not be a simple explanation, and those who studied the corrosion of various metals found an ever-opening field. Twenty years ago he had hoped to metal-spray turbine discs but there were reasons why one could not achieve full success. One came across different kinds of corrosion in boilers, bridges and ships. It

was the desire in all cases to produce self-healing films on metals, but one could not expect to find them for all alloys. Possibly they would be found for some, but they would be found more or less accidentally, and when found would be of great use.

Thickness of section was an important consideration in the corrosion of metal structures, and in aircraft the problem was at its worst, for the stresses were high and the vibration tended to throw off the all-important film from the surface.

On the motion of the CHAIRMAN, a hearty vote of thanks was accorded the authors of the paper.

FURTHER REPLY TO THE DISCUSSION (*Communicated*).

Writing in further reply to the discussion, the authors stated, with reference to the Chairman's remarks, that they fully appreciated his criticism. In the present paper, however, they had deliberately set out to deal with the practical side of a few typical corrosion problems appertaining to aircraft and aircraft materials. Discussion of the principles of corrosion and of the theoretical aspect of the subject was outside the intended scope of the paper. With regard to the point raised by Wing-Commander Scroggs concerning contamination of lubricating oil by lead, the authors stated that no serious cases of corrosion due to this cause had come to their notice. They appreciated his comments regarding attack of valves by leaded fuels and, although the use of Stellited valves gave a considerably improved life as compared with that of the older, untreated valves, it was agreed that trouble due to corrosive attack of valves was still sometimes experienced. Other alloys, such as the 80/20 nickel-chromium alloy, appeared to offer promise as valve materials for modern aircraft engines. Regarding the question of external corrosion of air-cooled cylinders, the authors were not aware of any processes, additional to cadmium-plating or aluminium-spraying supplemented by a suitable enamelling scheme, which were likely to be completely satisfactory for application to aero engine cylinders. In further reply to Mr. Nash the authors expressed regret that, at the moment, they had no data on the influence of " super-annealing " on the corrosion properties of D.T.D. 363 material, neither had they any experience of the corrosion resistance of the material after ordinary annealing treatment. They had observed, however, as stated in the paper, that under stress/corrosion conditions, material of this type was less resistant in the solution-treated condition than when fully heat-treated and aged. With reference to the corrosion behaviour of finally heat-treated and aged duralumin which had been subsequently reheated at 125°C., the authors had found that, after this treatment, duralumin was more liable to corrode by general surface pitting than material not reheated, but was not rendered seriously susceptible to intercrystalline attack. Replying to Mr. Nash's question concerning the corrosion characteristics of high-strength aluminium alloys, the authors did not think that one could generalise in the manner he suggested. As regards the occurrence of intercrystalline corrosion, the authors stated that, as a general rule, wrought aluminium alloys requiring elevated temperature ageing treatment for the development of their optimum tensile properties were more prone to intercrystalline corrosion than alloys which aged fully at ordinary temperature. In reply to Mr. Connolly, the authors pointed out that without an electrolyte there could be no electrolytic action between two dissimilar metals. When a couple consisting of two dissimilar metals or alloys was subjected to alternating stress in the presence of a corroding medium, the more electropositive metal or alloy would be expected to show the greater deterioration.

In conclusion the authors wished to thank Captain Pritchard, Dr. Sutton and Mr. Turner for their contributions to the discussion and for their very interesting observations. Mr. Turner, they considered, had put the reason for the corrosion of metals very clearly and the authors were inclined to agree with him that the complete prevention of corrosion in all metals and alloys is something which is extremely unlikely ever to be achieved.

# ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

*Issued by the*
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*(Prepared by R.T.P.)*

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*Machine Gun Defence Against Low Flying Aircraft.* (Lieut.-Col. Malvani, Rivista di Fanteria, May and July-August, 1938. W.T.M., No. 8, August, 1938, p. 384, and No. 2, Feb., 1939, p. 94.) (69/1 Italy.)

The article is of interest since it gives details of the number of hits by rifle and machine gun fire suffered by Italian low flying aircraft operating in Abyssinia.

In view of the short time the aircraft is under fire, it is essential that the gun control be as simple as possible. Best results are obtained by putting up a barrage through which the attacking aircraft must fly in order to attack the target. The gunner must know when to open fire and the angular lead required. For training, the author recommends miniature ranges, the target being at a distance varying between 2.5 m. and 30 m. Size of target, speed of travel and speed of bullet are arranged to correspond to the actual case. It is essential that the fire burst be always in front of the aircraft, the elevation being corrected subsequently as required. If tracer ammunition is used, the sight is only used for the first burst. Mixing tracer and ordinary bullets is not recommended.

It must always be remembered that the aircraft will drop its bomb whilst still at some distance from the target and the barrage must be placed accordingly. In conclusion some results obtained with machine guns against towed targets are given. At a distance of 110 m., 12 hits were scored for a burst of 445 rounds.

*The Problems of the Electro-Magnetic Gun.* (E. Rogge, Z.G.S.S., Vol. 34, No. 5, May, 1939, pp. 132-5.) (69/2 Germany.)

The author investigates in general terms the design of an electromagnetic gun consisting of 10 coils placed in series (total length 20 m.). A muzzle velocity of 1500 m./sec. is aimed at, the shell weighing 20 kg. and having a diameter of 10 cm. It is estimated that about 14,000 kw. of electrical energy will be required, the maximum current being of the order of several hundred thousand amps.

One of the main difficulties in the design will be the realisation of a sufficiently small time constant for the magnetic coils.

A further difficulty arises from the fact that it is not possible to rotate the shell and hence the stability of the trajectory will be poor.

Summing up the author considers that there exists very little prospect of the electromagnetic gun ever becoming a practical proposition.

*Maximum Speed of Projectile which can be Reached with Present-Day Explosives.* (H. Langweiler, Zeitsch. f. Techn. Physik., Vol. 19, No. 11, 1938, pp. 416-421.) (69/3 Germany:)

The motion of the projectile along the barrel of the gun necessarily produces a pressure difference between the base of the projectile and the closed end of the gun. The limiting projectile speed is reached when the pressure on its base has dropped to zero, *i.e.*, the projectile is moving at molecular velocity. Thus even if the gun is infinitely long, the explosive converted instantaneously into gas, and the mass of the projectile infinitely small, the speed is finite and (according to the author's calculation) of the order of 2800 m./sec. for a nitro cellulose powder. The molecular speed is increased if the explosive detonates. In this case nitro cellulose would give a limit of 3800 m./sec., whilst theoretical speeds of the order of 6000-7000 m./sec. are indicated for some other explosives of higher heat content. The author confirmed his prediction for the case of nitro cellulose (surface treated to give maximum rate of burning) by actually measuring the muzzle velocity of a series of projectiles of gradually decreasing mass by three different methods (perforation of wire, high speed cinema, shock wave, *i.e.*, Mach Angle). All three methods agreed in giving a limiting speed of 2790 m./sec. for this explosive.

*Merchant Marine Losses in the Spanish and Chinese Wars, Sept., 1936-Dec., 1938.* (U.S. Nav. Inst. Proc., Vol. 65, No. 436, p. 920.) (69/4 Denmark.)

According to statistics of a Danish Insurance Company, taking both theatres of war together, 160 ships were damaged and 106 totally lost.

It is interesting to note that 96 per cent. of the damaged cases were due to air attack, the remainder being accounted for by guns from ship or shore batteries. Of the total losses, 50 per cent. were due to attack by aircraft.

*The Audibility of Warning Sirens in the Presence of Street Noises.* (P. Baron, Comp. Rend., Vol. 208, No. 22, 30/5/39, pp. 1714-15.) (69/5 France.)

Typical street noises were recorded on a gramophone disc and reproduced electrically in a sound insulated room. In the same room was also reproduced the note of a siren of constant pitch (400/sec.). The intensity of the sound emitted by the siren as well as the noise level of the street record could be adjusted over wide limits. The degree of audibility of the siren was judged by six observers and was expressed as the fraction of the total experimental time during which the siren was audible above the street noises, for a given intensity of both note and noise. The following principal conclusions were drawn:—

1. Audibility changed from 15 per cent. to 90 per cent., for an increase in signal strength of 17 decibels.
2. For constant audibility, the signal strength must vary as the mean intensity of the street noise.
3. For general warning (untrained public) an audibility of 90 per cent. is required, *i.e.*, the intensity of the signal must be of the same order as that of the noise level.
4. Audibility is increased by a continuous change in frequency of the siren (constant intensity). A change in intensity at constant frequency produces a smaller audibility than the normal siren.

*The Air Force of the U.S.S.R.* (Quoted from Deutsche Wehr. L'Air, No. 472, 1/7/39, p. 429.) (69/6 Germany.)

The modern aircraft material of the U.S.S.R. amounts to 5,000 aircraft, of which 3,000 are fighters and only 500 heavy bombers.

The remainder of the fighting force (a further 5,000 machines) is considered to be obsolete.

The Russian fighters have shown up well in Spain and China. It must, however, not be forgotten that they were probably manned by picked crews. It is certain that the rank and file are very much inferior.

The industry is in need of skilled workmen, and matters are rendered more difficult by the periodical " purges " of the higher posts. It is significant that not a single aircraft engine of Russian design rated at above 1,000 h.p. is in production. The majority of the engines utilised are of American or French design and built under licence.

*Aeronautics and National Defence.* (I. I. Sikorsky, Mech. Eng., Vol. 61, No. 7, July, 1939, pp. 523-524.) (69/7 U.S.A.)

The Air Arm is a relatively new weapon which has as yet not been tried out on a really large scale. It appears likely, however, that results obtainable under such conditions will bear no resemblance to what occurred in the 1914-18 war. If a large town were raided by relays of bombers, say at the rate of 50 an hour, operating day and night for weeks on end, there is no doubt that life and work would become intolerable. Assuming 500lb. bombs are used by the raiders, the 50 machines could carry about 400 bombs. If these are dropped in line at intervals of about 150 feet, a line of destruction over a mile long would be created across which neither fire brigade nor ambulances could proceed. A fresh line would be created every hour, the menace being entirely a question of the number of aircraft available for the attack.

The author estimates that Germany is producing 30-40 good warplanes a day and this output could be doubled in an emergency.

*The Art of War—To-day and To-morrow.* (H. Foertsch, Germany General Staff; Publishers, W. Andermann, Berlin, 1939.) (69/8 Germany.)

War has been defined as the carrying out of a national policy by forceful means (Clausewitz), and according to Bismarck, " The purpose of war is to obtain a peace which corresponds to the requirements of the national policy." Although in the past wars were often fought for much narrower reasons than the above, it is thought that in the future state policies as expressed in alliances will ultimately decide over war and peace.

To carry out a war with any chance of permanent success thus implies a clear national policy, *i.e.*, the politician is more important than the general. On the other hand the general must be thoroughly familiar with a variety of new weapons and be able to ring the changes depending on circumstances.

His responsibility has thus increased enormously. The chances of breaking off an engagement and the resultant alternative periods of rest and activity which characterised the 1914-18 war are not likely to occur to anything like the same extent in a future campaign. In other words the fighting will be much more continuous.

The length of the campaign will depend on the relative " morale " of the opponents including the civilian population and this introduces a new factor.

A " lightning " campaign is, however, not probable unless the Air Force reveals itself capable of producing unexpected results when employed on a large scale.

*Further Development of a Boundary Layer Profile with a Given Pressure Distribution.* (H. Gortler, Z.A.M.M., Vol. 19, No. 3, June, 1939, pp. 129-140.) (69/9 Germany.)

The author develops a method for the calculation of the down stream development of a laminar velocity profile of known shape, the pressure distribution in the fluid being given. The method, although cumbersome, is accurate up to the point

of separation and can be applied in a number of cases where the well-known Blasius method fails.

As a practical test the author investigates the case of a circular cylinder, his theoretical prediction being in satisfactory agreement with experiments.

*Air Flow in the Boundary Layer of an Elliptic Cylinder.* (G. B. Schubauer, N.A.C.A. Tech. Report No. 652, 1939.) (69/10 U.S.A.)

The boundary layer of an elliptic cylinder, of major and minor axes 11.78 and 3.98 inches respectively, was investigated in an air stream in which the turbulence could be varied. Conditions were arranged so that the flow was two-dimensional with the major axis of the ellipse parallel to the undisturbed stream. Speed distributions across the boundary layer were determined with a hot-wire anemometer at a number of positions about the surface for the lowest and highest intensities of turbulence, with the air speed in both cases sufficiently high to produce a turbulent boundary layer over the downstream part of the surface. The magnitude and the frequency of the speed fluctuations in the boundary layer were also measured by the use of the conventional type of hot-wire turbulence apparatus. Stream turbulence was found to affect both the nature of transition from laminar to turbulent flow in the layer and the position on the surface at which transition occurred.

Transition was then investigated in detail with stream turbulence of several different scales and intensities. It was found that the position of transition could be expressed as a function of the intensity divided by the fifth root of the scale.

*New Methods of Calculation for Ventilators and Blowers of the Radial Type.* (B. Eck, Schweizer Bauzeitung, Vol. 113, No. 4, 28/1/39, pp. 1-7.) (69/11 Germany.)

In the case of radial blowers it is possible to give optimum theoretical values for entry diameter, blade angle and blade width at entry.

The author determines the effect of practical tolerances in these dimensions, special attention being given to the permissible curvature of the leading edge of the blades.

The investigation is extended to cover radial blowers with blades possessing double curvature.

Some notes on propeller fans are added.

*Lift Distribution on Wings Fitted with Lateral Disks.* (W. Mangler, L.F.F., Vol. 16, No. 5, 20/5/39, pp. 219-228.) (69/12 Germany.)

The author calculates the lift distribution of a wing fitted with vertical plates and thus resembling the horizontal tail planes of certain machines fitted with twin rudders. The calculation is carried out for the case of minimum induced resistance, the plates, although symmetrical, being not necessarily situated at the ends of the span.

The work thus presents an extension of a previous report of the author (L.F.F., Vol. 14 (1937) pp. 564-569) available as Air Ministry Translation No. 623.

At a given angle of incidence, the total lift of the wing increases with increasing height of plates and reaches a maximum when the plates are at the ends of the span. The lateral forces and moments acting on the plates reach a maximum when the plates are attached to the end of the span, provided the plates project only along one wing surface. In the more general case where the plate projects both above and below the wing, maximum forces and moments on the plate occur when the latter are at some small distance from the ends.

The result obtained with end plates is extended to cover the case of the wing with bent-up wing tips.

*Effect of Wing Load, Aspect Ratio and Load Distribution Along the Span on the Flight Performance.* (B. Gothert, L.F.F., Vol. 16, No. 5, 20/5/39, pp. 229-276.) (69/13 Germany.)

The following are the main conclusions:—

(1) An increase in wing loading is mainly beneficial in the case of fast aircraft operating at moderate altitude.
(2) With the increasing utilisation of aerodynamically efficient aircraft the choice of optimum wing loading becomes more restricted.
(3) In the case of long range aircraft (small power loading) it is beneficial to combine increase of aspect ratio with increase in wing loading.
(4) The optimum wing loading for condition of climbing is the greater, the greater the power and aspect ratio and the smaller the height.
(5) The aircraft is most sensitive to a departure from the optimum wing loading at small values of the power/weight ratio.

*De Havilland V.P. Airscrew, Pt. III.* (Machinery, 8/6/39, pp. 289-295. Metropolitan-Vickers Tech. News Bull., No. 665, 16/6/39, p. 4.) (69/14 Great Britain.)

The production of the blades for the de Havilland variable-pitch airscrew is described in this article. The blades are produced in several types and sizes, the majority of them being made from aluminium alloy forgings. Aerodynamic considerations of their form and profile necessitates a considerable amount of handwork. Reduction in the amount of this handwork is effected by the use of highly specialised shaping and turning tools as fully described. Methods of testing, balancing, grinding and anodizing the blades are dealt with in some detail.

Illustrated with 13 photographs and three diagrams.

*De Havilland V.P. Airscrew, Pt. II.* (Machinery, 1/6/39, pp. 257-262. Metropolitan-Vickers Tech. News Bull., No. 664, 9/6/39, p. 4.) (69/15 Great Britain.)

The production of the spiders, barrels and cylinders for the 5,000-type variable pitch airscrew made by the de Havilland Aircraft Co. Ltd., has already been dealt with in two previous articles. This article deals with the production of the remaining components of this airscrew including the counterweight bracket, the blade bush, and the barrel support. The set-up for milling the profile and radial slots and the various grinding operations as well as the system of inspection and testing used are described in detail.

Illustrated with 11 photographs and three sketches.

*An Approximate Spin Design Criterion for Monoplanes.* (O. Seidman, C. J. Donlon, N.A.C.A. Tech. Note No. 711, June, 1939.) (69/16 U.S.A.)

In the present state of knowledge, no criterion is available that will infallibly predict the recovery characteristics of a new aeroplane design. It is possible, however, to formulate empirical criterions that are helpful in establishing the minimum design requirements for safety in spinning. It is believed that the tail damping-power factor (TDPF)* developed by the author is a simple practical method for rapidly estimating whether a new design is likely to comply with

* Tail damping-power factor (TDPF) = Unshielded rudder volume coefficient × tail damping ratio.

$$= \frac{\text{Unshielded rudder area} \times l}{S(b/2)} \times \frac{\text{Total fixed area below horizontal tail surface} \times L^2}{S(b/2)^2}$$

where $l$ = distance of centroid of unshielded rudder area from C.G. of aircraft.
$L$ = distance of centroid of fixed area below horizontal tail surfaces from C.G. of aircraft.
$S$ = wing area.
$b/2$ = semi-span.

the minimum requirements for safety in spinning and it is recommended that no new monoplane design be constructed which possesses a TDPF of less than 0.00015. It should not be assumed, however, that a design which has a satisfactory TDPF will necessarily exhibit good recovery characteristics, as other factors not herein considered may influence the results.

*General Aeroplane Performance.* (W. C. Rockefeller, N.A.C.A. Tech. Report No. 654, 1939.) (69/17 U.S.A.)

Equations have been developed for the analysis of the performance of the ideal aeroplane, leading to an approximate physical interpretation of the performance problem. The basic sea-level aeroplane parameters have been generalised to altitude parameters and a new parameter has been introduced and physically interpreted.

The performance analysis for actual aeroplanes has been obtained in terms of the equivalent ideal aeroplane in order that the charts developed for use in practical calculations will for the most part apply to any type of engine propeller combination and system of control, the only additional material required consisting of the actual engine and propeller curves for the propulsion unit.

Finally, a more exact method for the calculation of the climb characteristics for the constant speed controllable propeller is presented in the appendix. This method replaces the approximate method, contained in the main body of the paper, in cases where the approximate method is not sufficiently accurate.

*An Introduction to Seaplane Porpoising.* (A. Klemin, J. D. Pierson and E. M. Storer, J. Aeron. Sci., Vol. 6, No. 8, June, 1939, pp. 311-318.) (69/18 U.S.A.)

Seaplane porpoising may be defined as an oscillatory combination of pitching and vertical motion of increasing amplitude.

Whilst independent motions in rise and pitch are usually stable in themselves, cross-coupling may produce instability.

Porpoising occurs both in alighting and take-off, but is generally more dangerous in the latter case since conditions of constant speed and trim may persist over a relatively long period.

The best way to check porpoising is to alter the angle of trim and endeavour to get through the dangerous region as quickly as possible. It appears that a change in C.G. position is only of use in so far as it affects the ease with which the pilot can control trim.

Porpoising tests on a hull alone may be very deceptive since the aerodynamic damping of pitching oscillation by the horizontal tail plane is not included.

The derivatives controlling the motion of a hull depend on a complex relationship between shape and speed and the magnitude of the coupled derivatives on which porpoising depends is thus not often known with sufficient accuracy. If, however, a complete test of the hull is available, the authors show how to predict the effect of certain change such as beam loading and trim angle.

*Some Structural Problems Pertaining to Pressurised Fuselages.* (L. F. Engelhardt, J. Aeron. Sci., Vol. 6, No. 8, June, 1939, pp. 319-322.) (69/19 U.S.A.)

Loads due to pressurisation have certain peculiarities which distinguish them from flight or landing loads. The magnitudes of the imposed loads are very accurately known, and cannot with the provision of suitable safety valves, be appreciably exceeded.

Since the structure is subjected to its maximum probable imposed loads for a considerable portion of its service life, this being its normal operating condition, the pressure shell should have an appreciable allowance for fatigue, material creep, etc.

Normal allowance is ample for variations in material or fabrication and for uncertainties of analysis methods because it is so simple by means of a proof test to check the strength of the shell with an authentic representation of the loads due to pressurisation.

A practical design might use the following design load factors:—

(1) For a steady flight condition superimpose upon the loads due to normal unaccelerated flight those due to the maximum probable pressure differential, the latter to be multiplied by a constant which would provide for fatigue, creep of the material, and the excess pressure possible before the safety valves can open. This factor should probably be between 1.25 and 1.50. Both flight and pressure loads should then be multiplied by the conventional 1.50 for design purposes.

(2) For momentary accelerations the pressure loads without the factor for fatigue, etc., should be superimposed on the critical limit flight loads. As before, both flight and pressure loads should be multiplied by the factor 1.50 for design purposes.

*A Comparison of Several Tapered Wings, Designed to Avoid Tip Stalling.* (R. F. Anderson, N.A.C.A. Technical Note No. 713, June, 1939.) (69/20 U.S.A.)

Optimum proportions of tapered wings were investigated by a method that involved a comparison of wings designed to be aerodynamically equal. The conditions of aerodynamic equality were equality in stalling speed, in induced drag at a low speed, and in the total drag at cruising speed. After the wings were adjusted to aerodynamic equivalence, the weights of the wings were calculated as a convenient method of indicating the optimum wing. The aerodynamic characteristics were calculated from wing theory and test data for the aerofoil sections. Various combinations of washout, camber increase in the aerofoil sections from the centre to the tips, and sharp leading edges at the centre were used to bring about the desired equivalence of maximum lift and centre-stalling characteristics.

In the calculation of the weights of the wings, a simple type of spar structure was assumed that permitted an integration across the span to determine the web and the flange weights. The covering and the remaining weight were taken in proportion to the wing area. The total weights showed the wings with camber and washout to have the lowest weights and indicated the minimum for wings with a taper ratio between 1/2 and 1/3.

*Tests of Two Full-Scale Propellers with Different Pitch Distributions at Blade Angles up to 60°.* (D. Biermann and E. P. Hartmann, N.A.C.A. Tech. Report No. 658, 1939.) (69/21 U.S.A.)

Two three-blade 10-foot propellers were operated in front of a liquid-cooled engine nacelle. The propellers differed only in pitch distribution; one had normal distribution (nearly constant pitch for a blade angle of 15° at 0.75 radius), and the other had the pitch of the tip sections decreased with respect to that for the shank sections (blade angle of 35° for nearly constant pitch distribution). Propeller blade angles at 0.75 R from 15° to 60°, corresponding to design speeds up to 500 miles per hour, were investigated.

The results indicated that the propulsive efficiency at a blade angle of 60° was about 9 per cent. less than the maximum value of 86 per cent., which occurred at a blade angle of about 30°. The efficiency at a blade angle of 60° was increased about 7 per cent. by correcting for the effect of a spinner and, at a blade angle of 30°, about 3 per cent. The peak efficiencies for the propeller having the washed-out pitch distribution were slightly less than for the normal propeller, but the take-off efficiency was generally higher.

*Supercharger Tests on Precombustion Chamber Diesel Engines.* (E. Schmidt, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 48-52.) (69/22 Germany.)

The majority of the experiments were carried out on two Daimler-Benz four-stroke Diesel locomotives normally rated at 300 and 400 h.p. respectively and fitted with exhaust driven superchargers of the Brown-Boveri type.

It appears that this type of engine is specially suited for supercharging, since the design is already characterised by low explosion temperatures. With increased boost, the ignition lag is reduced and there appears to be no difficulty in keeping the explosion pressure down to reasonable values by the simple process of altering the injection cam so as to reduce the initial rate of fuel injection. The author gives some examples of the importance of valve overlap and discusses the design of exhaust piping so as to ensure adequate scavenging.

The quantity of scavenge air required is much less than on a two-stroke engine. In the case of a locomotive normally rated at 300 h.p. and boosted to 450 h.p., the scavenge air only amounts to 24 per cent. of the total air consumption. Under these conditions, the induction pressure was of the order of 1.35 atm. abs., and the fuel consumption below 160 gm./b.h.p. hour.

It is stated that the altitude behaviour of the engine fitted with exhaust driven supercharger is very favourable and that an aircraft engine could be designed weighing not more than 0.7 kg./h.p.

*Effect of Piston Ring Material on Running Time.* (M. Kuhm, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 87-96.) (69/23 Germany.)

The experiments were carried out on an air-cooled single cylinder engine of approximately 1 litre volume running at 3,000 r.p.m. (C.R. 6.35, b.h.p. 23). Four different kinds of piston ring material were employed, the principal criterion being the duration of run before seizure of ring in grooves. Two kinds of seizure have to be distinguished :—

(*a*) Caking of oil in ring groove after an appreciable running time—heavy oil supply. In this case ring material has but little effect and the elasticity of the " freed " ring is not seriously impaired.

(*b*) Seizure in groove due to prior loss of elasticity, relatively short running time—small oil supply. This form of failure can be influenced by choice of material (type of cast iron).

Unfortunately ring materials capable of withstanding high working temperatures without serious loss of elasticity are not capable of forming good gas seals.

For this reason the author recommends composite rings, the outer member providing the seal and possessing good running-in qualities whilst the inner member is responsible for maintaining the contact pressure. The best running times on the test engine (150 hours) were obtained with a bimetal ring of bronze and cast iron of this type. With a very hard cast iron ring, on the other hand, seizure took place after as little as six hours.

*The Load Distribution in a Roller Bearing Connecting Rod.* (W. Hampp, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 102-6.) (69/24 Germany.)

The load distribution in a roller bearing can be calculated on the supposition of complete rigidity and absence of clearance. In practice the distribution differs appreciably from this depending on how the load is transmitted to the bearing (deformation due to elasticity of the rod).

Thus we may have a few rollers only taking the whole load or the deformation of the outer ring may cause a more or less uniform distribution of the load over a large number of rollers. In the first case, experiment showed that the roller pressures were from 25-45 per cent. greater than in the theoretical case. Sharing the load over a large number of rollers has, however, the disadvantage that

localities which are theoretically unloaded now experience high pressures without effectively contributing to the load capacity of the bearing. Each single roller is loaded over a relatively long path which reduces the life and induces skidding and tilting of the roller. This difficulty can be overcome to some extent by suitable design of rod. Attempt should be made to equalise as much as possible the load distribution under tension and compression and the forces should be introduced tangentially by the rod so that the roller pressure at right angles to the load is kept as small as possible.

*Problems in the Construction of Ball and Roller Bearings for Speed of Rotation Above* 20,000 *r.p.m.* (H. Merkle, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 107-109.) (69/25 Germany.)

The author deals shortly with the following aspects of the problem:—

1. Materials.
2. Manufacture.
3. Clearance.
4. Lubrication.
5. Installation.
6. Temperature.
7. Load carrying capacity.

Reference is made to reinforced synthetic resins as a suitable material for the cages of high speed blower bearings. Such cages are standard practice in the U.S.A.

Bearings up to 20 mm. bore and operating up to 30,000 r.p.m. can be lubricated satisfactorily with oil mist or spray. Larger bearings, however, must be pressure lubricated, a 25 mm. bearing requiring roughly 6 litres of oil per hour. Great care must be taken to prevent loss of oil to the outside. At the same time ample facilities must be given for the oil to leave the bearing, the exit pipe having at least ten times the section of the oil supply.

Properly designed bearings, carefully installed, have a life well in excess of 5,000 hours for bearing temperatures up to 130°C.

*Experiments on Ball and Roller Bearings Under Conditions of High Speed and Small Oil Supply.* (G. Getzlaff, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 110-118.) (69/26 Germany.)

The author describes a testing machine on which 35 mm. bearings (bore) can be run at speeds of the order of 20,000 r.p.m. whilst the following factors were recorded:—

(1) Oil circulation through bearing and temperature of oil.
(2) Maximum temperature of outer bearing ring.
(3) Radial and axial load on bearing.
(4) Radial, axial and angular clearance of bearing.
(5) Power consumption of bearing.

The experiments show that the lubrication was most reliable and oil consumption least when the oil was introduced through a hole in the outer or inner ring of the bearing. In the case of roller bearings the oil circulation could be kept especially low (0.5 *l/h* and less).

The temperature of the bearing is mainly determined by the radial clearance. A satisfactory performance could always be achieved on shafts without overhang provided the radial clearance was of the order of 30 $\mu$.

The axial load also increases the working temperature and it obviously pays to have oil of low viscosity.

Increasing the oil flow from 2 to 20 *l*/hour practically doubles the power consumption of the bearing.

*Vibrations of Helical Valve Springs.* (A. Hussmann, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 119-133.) (69/27 Germany.)

Valve spring vibrations are forced vibrations induced by higher harmonics of the valve lifting cam. It is possible to determine the relative importance of the forcing impulses from a harmonic analysis of the cam profile if the elastic constants of the spring and the damping are known. Conversely, it is possible to design cam shapes such that no notable spring vibrations occur over a given speed range of the engine.

The successful employment of such cams presupposes that the valve clearance is maintained small (of the order of 0.3 mm.).

*Investigations of the Causes of Breakage of Valve Springs.* (R. Hunlich and W. Pungel, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 134-140.) (69/28 Germany.)

Most of the breakages seem to be associated with surface defects (longitudinal grooves) produced during manufacture of the wire and aggravated by corrosion.

On deep etching, the broken wire often showed, in addition, peculiar notches of sharply defined saw tooth pattern. These notches are produced by fatigue when operating over a certain section of the Wohler curve, and their formation is apparently independent of the structure of the steel.

The author describes test results on 231 valve springs of which 136 broke. Of the total breakages only 23 showed no visible surface defects. Similarly of the 95 sound springs, 79 showed no surface defects.

*New Knowledge on the Production and Testing of High Quality Steel Wires with Special Reference to Valve Spring Wire.* (P. Kotzschke, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 319-325.) (69/29 Germany.)

Till relatively recently, most of the spring wire used in Germany was imported either in the form of plain carbon or chrome-silicon steel. The object of the present investigation is to demonstrate that wire at least as good as the imported article is now made in Germany For this purpose 15 tons of carbon steel ingots of similar composition to the Swedish imported wire were distributed to four different rolling mills to produce wire of 6.75 mm. diameter. This wire then went to two different wire drawing firms, the diameter being reduced to 3.9 mm. After drawing, the wire was heat treated (oil bath) and tempered (lead bath) and finally ground to 3.6 mm. diameter.

The springs were finally coiled by two different spring manufacturers and then subjected to an extensive examination, including etching (surface defects), fatigue strength (on a special testing machine) and surface cracks (magnetic powder test). Several thousand springs, of which all the past manufacturing history was known, were tested and compared with the best foreign product.

The article concludes with a description of the surface treatment known in America as " shot blasting." This is similar to sand blasting except that the blasting material must be small (less than 0.5 mm. diameter) and slightly harder than the steel.

The resultant " cold working " of the wire surface increases the fatigue strength of the material, provided the blasting is carried out with sufficient care.

*The Charging Process and Limits of Valve Operation in Four-Stroke Aero Engines.* (F. R. Schmidt, L.F.F., Vol. 16, No. 5, 20/5/39, pp. 251-275.) (69/30 Germany.)

The Lilienthal Society offered a prize for the best paper on this subject. The winning contribution has not been published, but the present paper as well as the essay forming the subject of Abstract No. 69/31 were awarded consolation prizes.

It is obvious that further attempts at a reduction in the specific weight of four-stroke aero engines can only be successful if increased boost pressure is accompanied by a further increase in r.p.m. It is interesting to note that with a given engine, the maximum performance at any boost recurs at the same r.p.m. The relative flow losses are thus constant and the optimum speed of operation is entirely a question of valve passage design, provided of course that no mechanical trouble due to valve operation arises at the higher speeds. The author considers this side of the problem very fully and concludes that the present four-stroke mechanism with poppet valves will be able to deal with such further increase in r.p.m. as is likely to arise in the near future, bearing in mind that ultimately the possible speed increase is limited by the piston cooling, and that improvements in the latter are bound to be slow.

*A Comparison of Valve Mechanisms (Poppet and Sleeve) as Regards Limiting Values of Compression Ratio, Mean Effective Pressure and Specific Fuel Consumption.* (T. Hoock, L.F.F., Vol. 16, No. 5, 20/5/39, pp. 276-282.) (69/31 Germany.)

In the case of poppet valves, a high temperature of the exhaust valve cannot be avoided and this puts an upper limit to the compression ratio and amount of permissible boost (detonation of charge).

The author describes the Cross rotary valve mechanism and gives some results obtained on small cylinders (under 500 c.c.). In this case the temperature of the valve mechanism can be kept quite low and provided the mechanism can be adapted to larger cylinders without difficulty, it should be possible to run a three-litre cylinder at a compression ratio of 9/1 with 87 octane fuel, giving a specific fuel consumption of about 170 gm. per b.h.p. hour (0.38 lb.).

It is recommended that further experiments be carried out with this valve mechanism, which is considered to be in some respects more promising than the Burt sleeve developed by Bristols. (According to the author the Burt sleeve distorts since one side is permanently cooled by the fresh charge. As a result, this kind of sleeve valve engine is strictly limited as regards overload.)

*Detonation and Combustion Chamber Design.* (K. Zinner, A.T.Z., Vol. 42, No. 9, 15/5/39, pp. 251-9.) (69/32 Germany.)

The " rest gas " responsible for the phenomenon of engine detonation receives heat by adiabatic compression and transfer from the flame front. But the most important source of heat energy resides in the " rest gas " itself and is associated with preliminary reactions of the chain type. The shape of the combustion chamber and especially the plug position will affect the amount of " activation " of the unburnt charge. Thus if the flame path is long, the available time for activation of the residue increases and with it the chance of detonation, unless care is taken to thoroughly cool all pockets, etc. An increase in combustion speed reduces the time of activation, but on the other hand increases the heat transfer to the residue brought about by compression. Generally speaking, the reduction in activation time is more important and therefore a turbulent combustion chamber is anti-knock.

The general problem of the relative importance of activation time and heat transfer is, however, very complicated and heat transfer tests under engine conditions are urgently required.

*Combustion Engines with Pneumatic Power Transmission.* (H. G. Hammar, E. Johansson, Trans. Inst. Marine Eng., May, 1939, pp. 139-154. Metropolitan Vickers Tech. News Bull. No. 664, 9/6/39, p. 11.) (69/33 Great Britain.)

This article discusses the " Götaverken " system of power transmission which it is claimed has been successfully applied to the propulsion of several types of

ships. The system comprises two sections—the prime mover or generator, and the propulsive unit. The former is a combustion engine, whilst the latter can comprise either a turbine or a reciprocating engine. Transmission is carried out by a mixture of air and hot gases produced in the combustion engine. The many advantages claimed for this system of propulsion over Diesel and steam engine propulsion, and its thermodynamics, are fully discussed.

The main feature is a combination of the manœuvrability of the steam engine with the low fuel consumption of the Diesel.

Illustrated with 14 diagrams and sketches.

*The Way to Increased Aeroplane Engine Power.* (E. Vohrer, Luftwissen, Vol. 5, No. 10, October, 1938, pp. 357-67. Available as Translation T.M. 894.) (69/34 Germany.)

As recently as three years ago a high output engine was defined as one delivering 25 h.p. per litre. This figure has now been raised to at least 30 h.p. for continuous and nearly 40 h.p. per litre for discontinuous operation (take-off).

Better fuels, more efficient superchargers and higher boost pressures together with increase in r.p.m. are responsible for this improvement. The limit is not yet in sight, since peak outputs of the order of 100 h.p. per litre have already been obtained in the laboratory with spark ignition engines (water injection for cooling).

According to the author the most promising way of realising such high power outputs in practice would be by adopting the two-stroke principle possibly in conjunction with a sleeve valve mechanism.

As petrol injection is already extensively used on four-stroke engines, its application to the two-stroke engine would present no great difficulties.

*Thin Oil Films.* (W. Claypoole, Trans. A.S.M.E., Vol. 61, No. 4, May, 1939, pp. 323-33.) (69/35 U.S.A.)

A method is described for depositing very thin lubricating oil films of any specified thickness of the order of $10^{-7}$ in. on polished metal in connection with experiments on boundary friction. The oil to be deposited is converted into a highly dispersed fog consisting largely of positively charged particles. The oil is readily deposited on a negatively charged metal surface at a rate depending on the nature of the oil, the potential gradient at the metal surface, and the concentration of the oil particles in the fog. The rate of deposition is best determined by observation of the progressive change in the interference colour produced over a thickness range between $4 \times 10^{-6}$ cm. and $30 \times 10^{-6}$ cm. Comparison of colour with a standard stepped film of barium stearate laid down by the Langmuir and Blodgett technique gives a high degree of accuracy to the determination of film thickness.

Experiments have been made on the wearability of very thin oil films, and on the determination of the coefficient of static friction. An instrument is described which has been found especially suitable for this work. The author points out that a low value of the coefficient of static friction is a measure of the oiliness value of an oil metal combination.

*Wear in Lubrication Problems.* (L. M. Tichvinsky, Trans. A.S.M.E., Vol. 61, No. 4, May, 1939, pp. 335-46.) (69/36 U.S.A.)

Boundary or semi-fluid friction takes place in bearings of practically all rotating machines when they are started or brought to a standstill. This type of friction, lasting a short period of time, is usually accompanied by the wearing of the bearing surface, the journal surface, or both. Wear takes place also in the case of anti-friction bearings due to sliding, rolling, or combined sliding and rolling friction. Many other causes, such as misalignment, dirt, or inadequate lubrication, might be responsible for wearing of any type of bearing. This paper

deals with the methods which are employed to obtain the wear resistance of various metals, especially those used in the design of bearings.

*A Comparison of Ignition Characteristics of Diesel Fuels as Determined in Engines and in a Constant-Volume Bomb.* (R. F. Selden, N.A.C.A. Tech. Note No. 710, June, 1939.) (69/37 U.S.A.)

Ignition lag data have been obtained for seven fuels injected into heated, compressed air under conditions simulating those in a compression-ignition engine. The results of the bomb tests have been compared with similar engine data, and the differences between the two sets of results are explained in terms of the response of each fuel to variations in air density and temperature.

CONCLUSIONS.

1. The rating order for certain Diesel fuels, as indicated by the ignition lags in the bomb, may change with variations in either air temperature of density.

2. Usually, the lower the air temperature and density at which ignition takes place, the greater is the spread between the ignition lags of two fuels.

3. With the exception of the marine Diesel fuel, the rating order obtained with the bomb was the same as that with an engine.

*The Ignition of Inflammable Gases by Hot Moving Particles.* (S. Paterson, Phil. Mag., Vol. 28, No. 186, July, 1939, pp. 1-23.) (69/38 Great Britain.)

1. A survey of the literature of ignition by hot surface suggests that the speed of relative motion of gas and surface is a factor determining whether ignition takes place; it is further surmised that increase of speed results in decrease of igniting power.

2. An apparatus for examining the effect of speed when the surface is that of a small sphere is then described in detail.

3. The results obtained with this apparatus are given. They apply to coal-gas-air and may be summarised as follows:—

(*a*) There is a minimum ignition temperature, for a given size of sphere, below which ignition has not been obtained.

(*b*) For temperatures above this minimum, ignition is regularly observed, provided that the speed does not exceed a critical value.

(*c*) This critical speed is a function of the temperature; it increases as the temperature is increased, according to a roughly linear relation.

(*d*) The slope of the temperature critical speed characteristic decreases (*i.e.*, the critical speed for any given temperature increases) as the richness of the mixture is increased from its value at the lower explosive limit.

(*e*) The characteristics for fused silica (" quartz ") spheres rise more steeply than those for platinum spheres of the same size, but the minimum ignition temperature is the same as before, and shows the same constancy with varying mixture strength.

(*f*) The platinum spheres are found to improve their igniting power with use.

(*g*) The initial temperature of the mixture appears to have no effect (over a range of 200°C.) on the minimum igniting temperature of a platinum sphere (2 mm.).

*An Electro-Magnetic Indicator and Knock Meter.* (J. Ratzke, Yearbook of German Aeronautical Research, 1938, Vol. 2, pp. 368-372.) (69/39 Germany.)

The principle of this instrument is similar to that of the electric extensometer described by the author in the 1937 Yearbook (Vol. 2, pp. 278-282). An alternating current bridge is fed with a high carrier frequency (of the order of 50,000/sec.) which becomes modulated depending on the motion of a soft iron armature moving in an inductive circuit. The armature is attached to a non-

magnetic diaphragm screwed into the combustion space, the whole recording unit having the outside dimensions of a normal sparking plug. For knock recording, the inductive circuit is simplified, one of the coils only being utilised. This coil is supplied with direct current and the resultant alternating p.d. produced by the motion of the armature when the engine knocks is recorded. The amplifying circuit is arranged so as to respond to the time variation of the p.d., *i.e.*, the final record corresponds to $d^2p/dt^2$.

Examples or records obtained on the C.F.R. engine under various conditions of operation show satisfactory working of the instrument as a knock meter.

*Pulsating Air Velocity Measurements.* (N. P. Bailey, Trans. A.S.M.E., Vol. 61, No. 4, May, 1939, pp. 301-8.) (69/40 U.S.A.)

This paper includes an analysis of the weaknesses of three methods of air velocity measurement, that is, (1) the hot wire anemometer, (2) the Thomas or Callendar meter, and (3) nozzles, orifices, or pitot tubes used with liquid manometers, and the author points out that all these methods give unreliable results when the air flow is pulsating. After analysing the influence of damping capacities the author describes a modified proportional flowmeter in which the pressure change of a nozzle, orifice, or pitot tube produces an air velocity through a small orifice which is always proportional to the instantaneous velocity of the main air flow; therefore, by measuring volumetrically the air that passes through the small orifice, the average velocity of the main air flow can be determined. Included in the paper are test results obtained with this meter on a $3\frac{1}{4} \times 4\frac{1}{2}$ in. single cylinder C.F.R. engine.

*Effect of Pulsations on Orifice Meters.* (S. R. Beitler, Trans. A.S.M.E., Vol. 61, No. 4, May, 1939, pp. 309-314.) (69/41 U.S.A.)

The paper describes three test set-ups made for investigating the effects of pulsations on orifice flow meters. Arrangements are described for subjecting meters to pulsations from either the inlet or outlet side and determining the error in measurement.

The work so far is admittedly preliminary, but the results show the extent and seriousness of the problem and point the way for further research which is of vital interest to the measurement industry.

*Corrosion on Electrical Measuring Instruments.* (F. Lieneweg, E.T.Z., 25/5/39, pp. 621-3. Metropolitan Vickers Tech. News Bull., No. 663, 2/6/39, p. 2.) (69/42 Germany.)

The author discusses the effect on electrical measuring instruments and measuring probes of corrosion which not only has a destructive effect on the material, but also affects the accuracy and reliability of measurement (corrosion due to electric current, leakage currents, precipitation of sulphur from rubber, frictional corrosion on steel points). He indicates remedies against the effects of such corrosion. Illustrated with three photographs.

*Collector Ring Films (Formation and Influence).* (V. P. Hessler, R. H. Savage, General Electric Review, May, 1939, pp. 192-7. Metropolitan Vickers Tech. News Bull., No. 663, 2/6/39, p. 10.) (69/43 Great Britain.)

The purpose of this article is to show something of the formation, nature and influence of corrosion film on sliding contact metallic surfaces. Most of the wide variation of resistance with current at the brush-ring contact is attributed to film formation, since a film-free ring exhibits essentially a constant resistance. Copper tarnish is only partially protective and corrosion may take place slowly through the oxide lattice. The existence and nature of the film can be determined by various physical and chemical means, but in an oxide layer on copper,

dielectric properties are so marked that resistance measurements are highly efficacious. The apparatus necessary to make such measurements and the author's interpretations of the results are given in detail.

Illustrated with one photograph and eight graphs.

*Altitude Effects on an Uncompensated Rate-of-Climb Meter.* (G. V. Schliestett, J. Aeron. Sci., Vol. 6, No. 8, June, 1939, pp. 323-8.) (69/44 U.S.A.)

The response of an uncompensated climb indicator to a sudden change in rate of climb and the accuracy of the indicated vertical speed during steady flight are treated as functions of altitude. Results of theory, laboratory tests, and flight tests are shown by non-dimensional curves. Agreement of the results is satisfactory. The observed flight responses of a climb indicator after sudden changes from level flight to actual climbs of 750, 1,050, and 2,150 ft. per min. are shown by curves of indicated and of actual rates of climb against time. Expressed in terms of non-dimensional quantities, these three curves are identical within the accuracy of flight tests.

The only compensation in this instrument is that which counteracts the effect of temperature on the properties of the materials in the pressure gauge. The air chamber is thermally insulated. The capillary is a glass tube that is not compensated in any way.

*Some Notes on the Schuler Principle—the 84 Minutes Pendulum.* (K. L. Stellmacher, Z.A.M.M., Vol. 19, No. 3, June, 1939, pp. 154-165.) (69/45 Germany.)

Schuler has shown that it is possible to compensate pendulum appliances against the effect of acceleration by utilising the change in the direction of gravity. This has led to the design of gyro-pendulums with an oscillation period of 84 minutes (*i.e.*, reduced length equal to the radius of the earth).

Schuler's principle has been very successfully applied in the gyro-compass. The proof given by him, however, is only valid if the accelerations act for a relatively short time. The author shows that this restriction is not necessary, provided the damping is sufficiently small. In the presence of finite damping, complete compensation against acceleration is not possible. There exists, however, an optimum period for which the effect of acceleration is least. This period is greater than 84 minutes if damping is present.

*Some Studies on Wire Drawing.* (M. Goto, H. Tanaka, Tokyo Aer. Res. Inst., No. 174, April, 1939, pp. 92-128.) (69/46 Japan.)

(1) When annealed wire which shows no sign of orientation is once drawn, it becomes oriented or fibrous. As it undergoes further drawings the degree of orientation is more pronounced. The rate of increase is not marked in the early stages of draft, but it becomes strikingly evident in the advanced stages.

(2) The fibrous nature of the wire increases as the centre of the wire is approached. At the extreme surface no sign of orientation is observed.

(3) If the draft per one pass is heavier, the wire becomes more fibrous provided it is carefully drawn.

(4) The more the lubricant diminishes the friction of a die, the more fibrous the wire becomes, that is, good lubrication imparts to the wire high degree of orientation.

(5) If the drawing speed is kept low the structure of the wire becomes more fibrous.

It has been found that if wire acquires a more fibrous structure, its mechanical properties, such as tensile and torsion strength are improved.

*Thermal and Electrical Conductivities of Some Magnesium Alloys.* (R. W. Powell, Phil. Mag., Vol. 27, No. 185 (Seventh Series), June, 1939, pp. 677-686.) (69/47 Great Britain.)

Results are given for the thermal and electrical conductivities of eight magnesium alloys at temperatures of 50°, 150° and 250°C. It is shown that these results can be represented to within 3.5 per cent. by the equation $K = 0.526 \times 10^{-8} \rho T + 0.027$, where $K$ is the thermal conductivity expressed in gram calories per square cm. per second for 1 cm. thickness and 1°C. difference in temperature, $\sigma$ is the electrical conductivity expressed in reciprocal ohms per cm. cube, and $T$ is the absolute temperature. An analysis is then made of existing data for the conductivities of magnesium and magnesium alloys, from which it is concluded that the equation $K = 0.516 \times 10^{-8} \rho T + 0.022$ can be used to give an approximate value for the thermal conductivities of such metals.

*A Note on the Nature of Sliding Friction.* (J. J. Bikerman, E. K. Rideal, Phil. Mag., Vol. 27, No. 185 (Seventh Series), June, 1939, pp. 687-92.) (69/48 Great Britain.)

If sliding friction is due to cohesion, " welding," or plastic flow, the value of the coefficient of friction must depend on the previous overloading of the surfaces in contact. As this after-effect cannot be detected for hard surfaces, the friction between hard surfaces cannot be due to the above-mentioned effects. On the other hand, Coulomb's theory ascribing friction to a lifting of the slider over irregularities finds a semi-quantitative confirmation in the absolute value of the coefficients of friction.

*Bearing Pressures and Cracks.* (H. M. Westergaard, J. App. Mech., Vol. 6, No. 2, June, 1939, pp. 49-53.) (69/49 U.S.A.)

Two solids are examined which, before loading, are in contact along a row of evenly spaced lines in a horizontal plane. Between these lines the surfaces have a separation defined by a nearly flat cosine wave. A uniform pressure on top of the upper solid creates contact over an area consisting of a row of strips, reduces the separation of the solids between the strips, and creates contact pressures with vertical rises in the diagram of pressure at the edges of the strips. At a greater load the width of the strip becomes equal to the wave length, and the contact is complete. At still greater loads the stresses increase as if the two solids were one. The procedure by which this problem is solved is demonstrated first by showing its easy application to some well-known cases, especially Hertz's problem of circular cylinders in contact.

*The Forces Required for Rolling Steel Strip Under Tension.* (A. Nadai, J. App. Mech., Vol. 6, No. 2, June, 1939, pp. 54-62.) (69/50 U.S.A.)

In the continuous mills which have been installed during the last ten years, wide strips of steel are being rolled hot or cold. While the sheets are reduced under the lateral pressure of the rolls, tensile stresses are set up in the rolled strips. The influence of front or of back tension on the roll pressures is investigated and a theory developed for the rolling process considering tension.

The localised compression of wide sheets or strips under simultaneous application of tensile stresses is discussed under various conditions of surface friction, such as solid friction, uniform surface shearing stresses or a resistance to slipping proportional to the relative velocity of slip. Simultaneous pulling reduces considerably the pressures otherwise required for deforming metal through concentrated compression.

The theory of the rolling of wide sheets is discussed with particular reference to the influence of front and of back tension upon the rolling pressures and the results of such computations are shown in several examples. Treatment of the

equations aims at a simplified use of certain variables and parameters which are needed in such computations.

*Numerical and Graphical Method of Solving Two-Dimensional Stress Problems.* (H. Poritsky, H. D. Snively, C. R. Wylie, Jr., J. App. Mech., Vol. 6, No. 2, June, 1939, pp. 63-6.) (69/51 U.S.A.)

In developing their numerical and graphical method for solving two-dimensional stress problems, the authors use a tension member with a semi-circular notch as an example. The procedure actually has, however, a wide range of application. Comparison of the calculated results and those obtained from photoelasticity shows close agreement. The maximum value of the stress in the plate used as an example obtained by this method is 3.25. This compares with a maximum of 3.20 obtained photo-elastically by Wahl and Beeuwkes and a maximum of 3.05 obtained in the same manner by M. M. Frocht.

*A Method of Calculating Energy Losses During Impact.* (C. Zener and H. Feshbach, J. App. Mech., Vol. 6, No. 2, June, 1939, pp. 67-70.) (69/52 U.S.A.)

When an elastic sphere collides with another perfectly elastic body, part of the initial kinetic energy is lost in starting elastic waves in the two bodies. The author develops an approximate analytical method for this calculation which is applicable even when the greater part of the energy is dissipated.

The powerfulness of the method is illustrated by a complete survey of the problem of impact of spheres with beams fixed at each end. Graphs are constructed showing the variation of the coefficient of restitution with the length of the beam and the mass of the sphere is kept constant. The coefficient of restitution has a minimum for a certain optimal beam length, and is independent of the beam length for values greater than twice the optimal length. The coefficient is a minimum when the period of the fundamental mode of vibration is approximately equal to 2.4 times the time of contact.

The method is also applied to the impact of spheres with large thin plates. The semi-empirical formula of Raman is derived.

*Calculation of Stresses within the Boundary of Photo-elastic Models.* (R. Weller and G. H. Shortley, J. App. Mech., Vol. 6, No. 2, June, 1939, pp. 71-8.) (69/53 U.S.A.)

A method is proposed for the determination of the internal stresses in a two-dimensional system from data furnished by a photoelastic analysis. The method involves the numerical integration of the Laplace difference equation over a region with known boundary values by the iteration of a set of improvement formulæ. The underlying theory is discussed briefly, reference being made to a more mathematical treatment appearing in another paper by the authors. New procedures for increasing the speed and accuracy of such computations are described and application is made to a typical photoelastic study. In this the complete system of internal stresses is computed, using the data obtained from the usual fringe photograph, without recourse to isoclinic lines, or other supplementary experimental measurements. The method is also applicable to other problems of potential theory which involve the vanishing of the Laplacian. These include electric fields, steady-state heat conduction, shapes of membranes, and problems in hydrodynamics and gravitation.

*Creep, Elastic Hysteresis, and Damping in Bakelite Under Torsion.* (H. Leaderman, J. App. Mech., Vol. 6, No. 2, June, 1939, pp. 79-85.) (69/54 U.S.A.)

The creep in torsion of various forms of bakelite under constant load and the creep recovery on removal of load is found to follow closely the superposition

principle or " memory law " of Boltzmann. If the previous maximum strain is exceeded, an additional plastic flow takes place which is not at any rate immediately recoverable.

A function of the elapsed time called the " equivalent time " is introduced in order to analyze the creep and creep recovery when the loading history is complex.

A method is developed for calculating the stress-strain loop due to creep for step-by-step cyclic loading. Results of cyclic-loading tests reveal the presence of a true elastic-hysteresis loop in addition to the loop due to creep.

The specific damping capacity in torsion at a given stress, calculated from the measured creep and elastic-hysteresis loop, is shown to agree fairly well with the damping measured directly.

*The Propagation of a Pulse in the Atmosphere.* (C. L. Pekeris, Proc. Roy. Soc., Vol. 171, No. 947, 7/7/39, pp. 434-449.) (69/55 Great Britain.)

It is shown that in a composite atmosphere, such as was assumed in a previous paper in connection with the theory of atmospheric tides, a surface pulse would excite waves of the first and second modes of oscillation, the amplitude of the former being greater than that of the latter by a factor varying from 2.4 to 2.9. This factor would tend to increase on account of dispersion. Some records of the atmospheric wave which was caused by the Krakatoa eruption of 1883 are discussed with a view to identifying the wave of the second mode. There are indications of this wave in the first passage and, to a lesser degree, in the second passage. The energy of these waves is estimated to be of the order of $10^{24}$ ergs. In the appendix is given the distribution with height of the vertical velocities in the two modes of oscillation of a model atmosphere. At heights of the order of 100 km., these velocities are found to be in phase with the surface pressure for both modes.

*A Preliminary Study of the Prevention of Ice on Aircraft by the Use of Engine Exhaust Heat.* (L. A. Rodert, N.A.C.A. Technical Note No. 712, June, 1939.) (69/56 U.S.A.)

An investigation was made in the N.A.C.A. ice tunnel at air temperatures from 20° to 28°F. and at a velocity of 80 miles per hour to determine whether ice formations on a model wing could be prevented by the use of the heat from the engine-exhaust gas. Various spanwise duct systems were tested in a 6-foot-chord N.A.C.A. 23012 wing model.

The formation of ice over the entire wing chord was prevented by the direct heating of the forward 10 per cent. of the wing by hot air, which was passed through leading-edge ducts. Under dry conditions, enough heat to maintain the temperature of the forward 10 per cent. of the wing at about 200°F. above that of the ambient air was required for the prevention of ice formation. The air temperature in the ducts that was necessary to produce these skin temperatures varied from 360° to 834°F.; the corresponding air velocities in the duct were 152 and 45 feet per second.

Ice formations at the leading edge were locally prevented by air that passed over the interior of the wing surface at a velocity of 30 feet per second and a temperature of 122°F.

Existing data indicate that sufficient exhaust heat is available; the problem is, therefore, to determine how this heat can be utilized to the best advantage or, in other words, the problem is one of distribution.

*Report of the French Committee on Ice Formation on Aircraft.* (Pub. Sci. et Tech. du Min. de l'Air, B.S.T. No. 85, 1939.) (69/57 France.)

This Bulletin, published in March, 1939, covers the Committee's findings of May, 1938.

As is well known, ice deposits on the wings and control surfaces are dangerous since they have a critical effect on the performance of the aircraft. It is obvious that under these conditions full engine power is of special importance and for this reason both the carburettor and propeller must be protected from any possible ice effect. This part of the problem is relatively simple and any failure on this account can only be attributed to carelessness.

As regards methods of overcoming wing icing, matters are more complicated and no completely satisfactory solution is known so far. The Goodrich mechanical deicer is satisfactory as regards the nose, but cannot be applied to slots and flaps without considerable complication.

The Committee seem to consider that a thermal method of getting rid of the ice is promising and in this connection seem to favour the electrical production of the necessary heat.

The obvious utilisation of the waste exhaust heat of the engine for this purpose is considered to be impracticable (see Abstract No. 69/56 for American experiments with exhaust heat deicers).

*Detection of Turbulence of a Liquid by Means of Polarisation.* (E. A. Hanser and D. R. Dewey, Ind. and Eng. Chem., Ind. Ed., Vol. 31, No. 6, June, 1939, p. 786.) (69/58 U.S.A.)

The use of transparent plastics in the construction of models for hydraulic research work is receiving increasing attention. Up to recently turbulent zones of flow in such systems were rendered visible by the addition of dyes to the liquid.

As an alternative the phenomenon of double refraction of colloidal dispersions can be utilised and has proved very useful especially at low rates of flow.

Anisometric particles will always tend to orientate themselves with one axis parallel to the direction of flow and this orientation is readily detected by placing the transparent container between crossed polaroid films and illuminating with strong diffuse light. Highly diluted water dispersions of natural bentonite have proved very suitable for such work. Such dispersions are prepared by fractionating in a supercentrifuge, the particles utilised being less than 50 m.$\mu$. The mixture is practically clear to the eye and exhibits pronounced birefringence at low rates of flow for temperatures up to the boiling point of water.

*Resolving Power and Distribution of Typical Aeroplane Camera Lenses.* (F. E. Washer, Bur. Stan. J. Res., Vol. 22, No. 6, June, 1939, pp. 729-746.) (69/59 U.S.A.)

Tabulations are given of the resolving power and distortion of a number of aeroplane-camera lenses of the type most commonly used in recent air-mapping projects. Since the image plane of best average definition does not necessarily coincide with the image plane yielding best definition on the axis of the lens, the method of selecting the image plane of best average definition and its use in connection with the determination of the equivalent focal length are described. The manner of the variation of the resolving power across the field is characteristic of the type of lens.

*Standardisation of the Luminous Transmission Scale Used in the Specification of Railroad Signal Glasses.* (K. S. Gibson, G. W. Haupt, Bur. Stan. J. Res., Vol. 22, No. 6, June, 1939, pp. 627-649.) (69/60 U.S.A.)

This is the first of several papers dealing with the development and description of the signal-glass specifications formulated by the signal section of the Association of American Railroads in 1935 and 1938. The present paper gives the spectral transmissions of the basic standards—red, yellow, green, blue, purple, and lunar-white glasses—on which the AAR scale of luminous transmission is based, and defines that scale in fundamental, absolute units. Comparison is made with the scales defined in the 1908 and 1918 signal glass specifications.

*Experiments on the Variation of the Electrical Resistance of Wires when Under Tension.* (E. Czerlinsky, Yearbook of German Aeronautical Research, Vol. 2, 1938, pp. 377-380.) (69/61 Germany.)

Measuring devices which depend on the variation of the electrical characteristics of a circuit are well known. These variations may affect the induction, capacity or resistance. As regards the latter method of control, the pressure response of the carbon pile resistance is well known. The author investigates the variation in resistance of metallic conductors when under tension. This change consists of two parts, namely a portion which can be calculated from the change in shape of the wire under load and a remainder which depends on a change in the specific resistance of the material with load.

If the electrical resistance is to be utilised for recording the tension of the wire, it is important that the change in resistance be relatively large, that the temperature coefficient be small and that the change in specific resistance with load be small. Of the various materials tested, it appears that constantan is most suitable for the purpose in view. The load resistance curve for nickel is peculiar in that the resistance first diminishes and then increases with increasing tension. The behaviour can be explained in terms of progressive orientation of the magnetic nickel molecules (magneto striction).

*Electrical Model Experiments for the Solution of Heat Transfer Problems.* (F. Bruckmayer, Z.V.D.I., Vol. 83, No. 10, 11/3/39, p. 316.) (69/62 Germany.)

The similarity between temperature fields and those of electric potential can be used for the solution of heat flow problems by measuring the electric resistance of thin tin foil having the section of the conducting substance. This resistance, measured in the direction of the heat flow, is compared with that of a rectangular calibrating strip, and gives the " form " factor for the thermal resistance of the section. The author found good agreement between the measurements and calculations for various simple geometrical shapes.

The method can also be employed for tracing the isotherms of insulators.

*Blind Landing System.* (Inter. Avia., No. 654-5, 27/6/39, pp. 10-11.) (69/63 U.S.A.)

Invented by Edward N. Dingley of the Navy Department, the device consists of an electrically magnetized cable buried beneath the main runway of the field. The deflection of a magnetic needle on the plane's instrument board shows the location of the plane with relation to the runway. The magnetic field is said to extend for a distance of 9,000ft. from any point on the runway.

## LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the supply of copies of translations mentioned below should be addressed to the Under-Secretary of State (R.T.P.), Air Ministry, Berkeley Square House, W.1, and will be supplied, free of all charge, as far as availability of stocks permit. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

Lists of selected translations have appeared in this publication since September, 1938.

### THEORY OF WARFARE.

| TRANSLATION NUMBER AND AUTHOR. | TITLE AND JOURNAL. |
|---|---|
| 908 Raienko, N. ... ... | *Calculation of a Convoy Flight.* (Air Fleet News, U.S.S.R., Vol. 20, No. 4, April, 1938, pp. 74-5.) |
| 909 Bruno, G. ... ... | *Bomb Trajectories Calculated by a Development of the Siacchi Method.* (Rivista Aeronautica, Vol. 14, No. 8, August, 1938, pp. 266-88.) |
| 914 Alimov, A. ... ... | *Bombing Aircraft of the Japanese Air Force.* (Air Fleet News, U.S.S.R., Vol. 20, No. 4, April, 1938, pp. 58-69.) |
| 921 Hombracht, F. J. ... | *Protection of Buildings Against Incendiary Thermite and Electron Thermite Bombs.* (De Ingenieur, Vol. 53, No. 37, 16/9/38, pp. 161-3.) |
| 923 Rizzetto, R. ... ... | *Effect of a Bomb Exploding at Some Distance from a Building.* (Riv. Aeron., Vol. 14, No. 11, November, 1938, pp. 267-72.) |

### AERODYNAMICS AND HYDRODYNAMICS.

| | |
|---|---|
| 378 Schmidt, R. ... ... | *Scale Effect in Towed Tests with Aeroplane Flotation Units.* (Luftfahrtforschung, Vol. 13, No. 7, 20/7/36, pp. 224-37.) |
| 913 Thiel, H. ... ... | *The Effect of Shape of Float and Loading on the Water Resistance of Floats.* (Luftwissen, Vol. 6, No. 1, January, 1939, pp. 30-5.) |
| 917 Naumann, A. ... | *Pressure Distribution on Wings when Incident Flow is from the Back.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 1, 1938, pp. 20-100.) |

### ENGINES AND ACCESSORIES.

| | |
|---|---|
| 910 Jellinghaus, W. ... | *The Unit Power Plant—Advantage of Power Installations which can be Quickly Exchanged.* (Luftwissen, Vol. 6, No. 1, January, 1939, pp. 24-9.) |
| 922 Gohlke, — ... ... | *Survey of Patents Dealing with Thermal Air Jet Propulsion.* (Flugsport, Vol. 31, No. 1, 4/1/39, pp. 1-5; No. 2, 18/1/39, pp. 31-7; No. 3, 1/2/39, pp. 70-5; No. 4, 15/2/39, pp. 100-4.) |

| TRANSLATION NUMBER AND AUTHOR. | | TITLE AND JOURNAL. |
|---|---|---|
| 924 | Dierbach, E. ... ... | *Plant for Pre-Heating Aero Engines.* (Z.V.D.I., Vol. 80, No. 43, 24/10/36, pp. 1301-2.) |
| | | METEOROLOGY. |
| 916 | Laureri, E. ... ... | *A Case of Lightning Striking an Aeroplane in Flight.* (Rivista Aeronautica, Vol. 14, No. 9, September, 1938, pp. 491-502.) |
| 919 | Lautner, Dr. ... ... | *Balloon Barrages and Atmospheric Electricity.* (Luftwissen, Vol. 5, No. 2, February, 1938, pp. 66-70.) |
| | | AIRCRAFT AND ACCESSORIES. |
| 907 | Kramar, E. ... ... | *Problems of Wireless Navigation for Aircraft.* (Luftwissen, Vol. 5, No. 10, October, 1938, pp. 369-74.) |
| 912 | Janovsky, W. ... | *Telephone Equipment for Use in Aviation.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 3, 1938, pp. 41-5.) |
| 915 | Malannino, — ... | *The Practical Design of Aircraft Undercarriages.* (L'Aerotecnica, Vol. 18, No. 7, July, 1938, pp. 813-28.) |
| 925 | Oeckl, O. ... ... | *The Utilisation of Electron as a Material for Dies—Methods of Production Employed by the Henschel Aircraft Works.* (Henschel Works Bulletin (Henschelstern) No. 10, October, 1938, pp. 234-9.) |
| | | MISCELLANEOUS. |
| 911 | Jarky, E. ... ... | *A Method for Checking Altimeters with Hermetically Sealed Bodies.* (Air Fleet News, U.S.S.R., Vol. 20, No. 4, April, 1938, pp. 97-8.) |
| 918 | Schmieschek, V. ... | *Increasing the Sensitivity of Silver Halides in the Colloidal State in Gelatine.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 3, 1938, pp. 78-83.) |
| 920 | Coermann, R. ... | *Investigations of the Effect of Vibrations on the Human Organism.* (Jahrbuch der deutschen Luftfahrtforschung, 1938, Vol. 3, pp. 111-40.) |

## REVIEWS.

AIRCRAFT DESIGN. (Vol. II.)

By C. H. Latimer Needham, M.Sc., F.R.Ae.S. Published by Chapman and Hall, Ltd. Price 16/-.

This is the second volume of a work on aircraft design, and it discusses structural matters. The first volume is concerned principally with aerodynamics.

It is rather difficult to evaluate a book of this type. It is true that a person who has a small mathematical knowledge and who wishes to stress an aeroplane, might succeed in doing so if he followed patiently the instructions given here. But he would be probably equally successful if he studied the relevant Air Ministry publications, and had access to, say, the Handbook of Aeronautics. He would not, in either case, be able to put more than a rough idea about the theoretical basis on which many of the formulæ presented to him are founded. For this, he would have to consult one of the standard books on stress matters.

Even this book does not contain everything that may be wanted. For instance, if Berry Functions are required, the reader is referred to A.P. 970. Again, there is no reference to the not unimportant matter of form factors. Airscrews are dealt with in a distinctly sketchy manner, and it is permissible to doubt whether it would not have been better to leave them out altogether rather than to treat them in this way. On the other hand, this book is better written than the first volume and shows evidence of greater care in its preparation.

The book should be regarded as a handbook rather than a textbook, and as such comes directly into competition with the Handbook of Aeronautics. Of the two, I much prefer the latter, but Captain Latimer Needham's book is rather cheaper.

" DIE LUFTMAECHTE EUROPAS, ASIENS, AMERIKAS, AFRIKAS, AUSTRALIENS." (The Air Powers of Europe, Asia, America, Africa, Australia.)

Vol. 2 of " Europa—Kraefte und Wirkungen, Soldatische Einweisung im Sinne totaler Wehrbereitschaft " (Europe, Forces and Actions. Soldier's Instruction in View of Complete Preparedness for Defence). Summer, 1939. Published by Verlag Bernard and Graefe, Berlin. 97 pp., one map of Europe. Price R.M. 1.75.

As no author's name is given it appears that the information contained has been compiled by service departments. The intention is—according to a preface contributed by the publisher and dated May 22nd, 1939, " the day of the signature of the German-Italian Alliance "—to explain definitions of aerial warfare and to give a basis for the valuation of present air powers and air armaments. The actual figures given are said to be compiled from technical papers and similar sources.

As to the comparative value of an air power the author states that any comparison based on total sums of aeroplanes is misleading.

For Great Britain the following figures are given:—

Home: 1,751 aeroplanes (560 fighters, 855 bombers, 24 torpedo bombers, 216 coastal reconnaissance, 96 army co-operation).

Overseas: 354 aeroplanes.

Naval Air Arm: Approximately 240 aeroplanes.

Concluding, it is said that the air force of Great Britain " may become " an important factor of power in Europe, and the author alleges the " sporting flying training " to be good. The air force of France is said to possess a very high standard of training and to have a considerable reserve of personnel. Italy's air force is stated to be by far the strongest in the Mediterranean sea and to be technically and personally of the highest order. Soviet Russia's air force is

still technically mainly based on foreign assistance and might experience fundamental difficulties in an emergency.

For Germany no figures and no description of the organisation is given, but in the introduction Germany's air force is stated to be superior to that of any other country and is resolved to remain so. Reference is drawn to Colonel Lindbergh, who is said to have stated in May, 1939, that Germany is in front of England and Italy, that France comes fourth, and that the Soviet Russian air force is an unimportant factor.

An annex gives particulars of all aircraft carriers of the world.

ELEMENTS OF PRACTICAL AERODYNAMICS.

By Bradley Jones, M.S. Published by John Wiley and Sons, Inc. (Chapman and Hall, Ltd., London.) Price 18/6.

This is the second edition of this book. It contains the same material as the first edition, but it has been brought up to date by the additional matter.

This book is a typical American textbook intended for class-room use, and the claim is made that the subject matter is presented in the simplest possible manner and that only elementary algebra is necessary to understand it. This result is obtained largely by leaving out proofs. For instance, Bernoulli's equation is introduced suddenly in the chapter on propellers without any explanation about what it means or how it is derived. Another peculiarity from the British point of view is the use of " engineering coefficients " in certain chapters in which $V$ is in miles an hour.

The author is usually clear in his descriptions, but there is a paragraph in his chapter on engines on coolants which is not at all easy to follow. The student might easily get the idea that water is much heavier than ethyl glycol and there is no real indication of the fact that the hotter the radiator the smaller it can be made, with advantages in the direction of weight saving and air resistance. The fuel consumption of a Diesel aero engine is not normally half that of a petrol aero engine in lbs. per horse-power.

This type of book is probably very suited to American methods of teaching, which differ from those used here.

OLEG HOEFFDING: " DIE NICHT-EISEN-METALLWIRTSCHAFT IN DER SOWJETUNION."

(The Economics of Non-Ferrous Metals in Soviet Russia.)

Bleicherode am Harz, 1939. Published by Verlag Carl Nieft. 152 pp., 5 maps.

The non-ferrous metals such as copper, lead, aluminium, nickel and tin, which are alleged to be recognised in Soviet Russia itself as war materials, are considered in this book from a purely economical viewpoint as well as with regard to defence economics and general national economics.

The first part deals with the raw material situation and quotes a large amount of figures for the different mineral contents and for past and present production. The production facilities and the production planning are fully discussed, and full reference is given as to the sources of the information. The economic and social problems of the Russian non-ferrous metal industry form the second part. The inner political and social difficulties influencing output and future progress are fully discussed with frequent quotations from Russian publications, in order to show the failure of the Soviet Russian planned economics.

The production of aluminium, which started only in 1916 in Russia, had grown up to approximately 37,000 tons in 1936, 31 per cent. of which were used for the construction of aircraft and vehicles, and bigger output is on the way. Bauxite has been found in at least five different places in Russia and Siberia, and other aluminium minerals are in abundance, but it is stated that the quantities available in Yugoslavia, Hungary and Dutch Guiana are by far larger.

For those interested in the economic side of the metal industry this book will be valuable.